



**COLORADO**  
Department of Public  
Health & Environment

## Air Pollution Control Division

## Technical Services Program

### **APPENDIX GM1**

Standard Operating Procedure for the Determination of  
Carbon Monoxide in Ambient Air

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## Standard Operating Procedure for the Determination of Carbon Monoxide in Ambient Air

### 1 SCOPE AND APPLICABILITY

#### 1.1 Introduction

This standard operating procedure (SOP) document describes the procedures used by members of the Air Pollution Control Division (APCD) Technical Services Program (TSP) to operate continuous carbon monoxide (CO) analyzers at the State of Colorado, Department of Public Health and Environment's (CDPHE) air quality monitoring sites. This includes both standard and trace level analyzers at State and Local Air Monitoring Stations (SLAMS), special purpose monitoring (SPM) and NCore monitoring stations. The CDPHE uses the Thermo 48i-TLE trace level analyzers in its air monitoring network. The procedures given in this SOP are a supplement to APCD's Quality Assurance Project Plan (QAPP), the latest information published in the Code of Federal Regulations, and the Operator's manual for Model 48i Trace Level-Enhanced CO analyzer (48i-TLE)

#### 1.2 Method Overview

Non-dispersive infrared spectroscopy has been designated as the U.S. EPA reference method for measuring carbon monoxide in ambient air. The lower detection limit (LDL) is defined in [Table B-1](#) of the Code of Federal Regulations, Title 40, Subpart B, Section 53.20, or, in the shorthand format used hereafter, 40 CFR 53.20. For trace level analyzers (Thermo 48i-TLE), the LDL is 0.2 ppm. For reference, the carbon monoxide standards are 35 ppm for the 1-hour concentration not to be exceeded more than once per year, and 9 ppm for the 8-hour average concentration not to be exceeded more than once per year ([40 CFR 50.8](#)).

#### 1.3 Format and Purpose

The sequence of topics covered in this CO method follows 2007 EPA guidance on preparing standard operating procedures (SOPs). This method was also written to help field operators understand why (not just how) key procedures are performed (US EPA, 2007).

### 2 SUMMARY OF METHOD

The analytical principle is based on absorption of infrared (IR) light by the CO molecule. Non-dispersive infrared and gas filter correlation (NDIR-GFC) analyzers operate on the principle that CO has a sufficiently characteristic IR absorption spectrum such that the absorption of IR by the CO molecule can be used as a measure of CO concentration in the presence of other gases. CO absorbs IR maximally at 2.3 and 4.6  $\mu\text{m}$  (ref. 1). Since NDIR is a spectrophotometric method, it is based upon the Beer-Lambert law. The degree of infrared radiation reduction depends on the length of the sample cell, the absorption coefficient, and CO concentration introduced into the sample cell, as expressed by the Beer-Lambert law shown in the equation below:

#### Equation 1. Beer-Lambert Law

$$T = \frac{I}{I_o} = e^{(-axC)} \quad (1)$$

where:

T = Transmittance of light through the gas to the detector  
I = light intensity after absorption by CO  
I<sub>o</sub> = light intensity at zero CO concentration  
a = specific CO molar absorption coefficient  
x = path length, and  
C = CO concentration

For GFC, there is only one sample cell. This cell acts as the sample and reference cell. A broad band of IR radiation is emitted from an IR source. The IR light passes through a very narrow band pass filter which screens out most wavelengths and allows only the light that CO absorbs to enter the sample cell. The GFC analyzer has a chopper wheel with cells containing two pure gases: nitrogen ( $N_2$ ) and CO. As the chopper wheel rotates and allows the IR energy to enter the “CO side” of the wheel, all IR energy that could be absorbed by CO in the sample stream is absorbed by the CO in the wheel. This technique effectively “scrubs out” any light that could possibly be attenuated. The single detector records the light intensity ( $I_0$ ). As the wheel spins, the “ $N_2$  side” of the wheel enters the IR energy beam. This side of the wheel allows all IR light to pass through the wheel and be absorbed by any CO that might be in the sample gas. This light level is CO sensitive ( $I$ ). The detector records the attenuation of this light, compares the two light levels ( $I/I_0$ ) and sends a signal to the electrometer board that calculates the concentration. The voltage is related to the CO concentration according to the Beer-Lambert law, as shown in the equation above. In this way the carbon monoxide instruments can measure CO continuously.

The 48i-TLE version has four distinct features that allow it to measure CO at sub-ppm trace levels:

- required sample stream dried using permeation dryer;
- analyzer baseline determined and corrected using heated Carulite catalytic converter;
- frequent auto-zero, APCD uses an every six hour cycle; and
- an ultra-sensitive or “hot” detector.

With the improved rejection of interferences afforded by the GFC technique, it is possible to increase the sensitivity of the analyzer. This is achieved by the multiple pass optics used in the sample cell, which leads to a large path length, and thus an improved sensitivity, in a small physical space. This allows full scale sensitivity down to 0.40 ppm with a LDL of 0.20 ppm to be achieved.

### **3 DEFINITIONS**

The CDPHE/APCD/TSP QAPP contains an appendix of acronyms and definitions. Any commonly used shorthand designations for items such as the sponsoring organization, monitoring site, and the geographical area will be defined and included in this SOP or in the QAPP Appendix P2.

### **4 HEALTH AND SAFETY WARNINGS**

#### Chemical Hazards:

Purafil is used in the zero air generators to remove nitrogen oxide from air. Sodium permanganate is a component within Purafil and should be handled with care. Sodium permanganate is a known irritant and care should be taken to avoid exposure to open wounds, burns or mucous membranes. Prolonged exposure (usually over many years) to heavy concentrations of manganese oxides in the form of dust and fumes, may lead to chronic manganese poisoning, chiefly involving the central nervous system.

#### Gas Hazards

Carbon monoxide (CO) is a colorless, odorless and tasteless gas. It is a hazardous compound as it combines with hemoglobin and reduces the oxygen carrying ability of the blood. Carbon monoxide is produced by the incomplete combustion of fossil fuels. In major urban areas of developed nations, its major source is the exhaust from light-duty motor vehicles.

As CO is a poisonous gas, calibration source tanks and delivery systems, or any other calibration span gas, should be vented to the atmosphere rather than into the shelter or other sampling area. The majority of APCD’s sites vent inside the shelter. The concentrations vented by the delivery systems are low and below the OSHA action levels of

50 ppm. However if the operator experiences lightheadedness, headache or dizziness, the operator must leave the area immediately and limit exposure to CO by getting fresh air every 5 to 10 minutes.

#### Electrical Hazards

1. Always use a third ground wire on all instruments.
2. If it is necessary to work inside an analyzer while it is in operation, use extreme caution to avoid contact with high voltage inside the analyzer. The analyzer has high voltages in certain parts of the circuitry, including a 110 volt AC power supply. Refer to the manufacturer's instruction manual and know the precise locations of these components before working on the instrument
3. Avoid electrical contact with jewelry. Remove rings, watches, bracelets, and necklaces to prevent electrical burns.
4. Always unplug the analyzer whenever possible when servicing or replacing parts.

#### **5 CAUTIONS**

To prevent damage to the equipment, the following precautions should be taken:

1. In the event that it is necessary to clean the optical bench, be careful to avoid damaging the interior of the sample chamber. In addition, some instruments have a series of mirrors that deflect the light in order to increase the path length. The mirrors are aligned at the factory. If the mirrors become misaligned, the IR light beam will not be directed to the detector. Use extreme caution when cleaning or servicing the sample chamber(s). In addition, the mirrors are very fragile. Avoid dropping the instrument. This may damage, misalign or crack the mirrors and cause expensive repairs. Clean the optical bench carefully to avoid damaging the interior of the bench, cleaning should be performed only if needed. Use cleaning procedures outlined in the manufacturer's instruction manual. Avoid touching the mirrors unless cleaning is absolutely necessary.
2. Keep the interior of the analyzer clean.
3. Inspect the system regularly for structural integrity.
4. To prevent major problems with leaks, make sure that all sampling lines are reconnected after required checks and before leaving the site.
5. Inspect tubing for cracks and leaks. The permeation dryer (48i models) may rest upon parts that vibrate, such as the air pump. Check the areas of the permeation dryer where they come into contact with other parts.
6. It is recommended that the analyzer be leak checked after replacement of any pneumatic parts.
7. Use and transport of cylinders are a major concern. Gas cylinders may contain pressures as high as 2000 pounds per square inch. Handling of cylinders must be done in a safe manner. If a cylinder is accidentally dropped and the valve breaks off, the cylinder can become explosive or a projectile.
8. Transportation of cylinders is regulated by the Department of Transportation (DOT). It is strongly recommended that all agencies contact the DOT or Highway Patrol to learn the most recent regulations concerning transport of cylinders.
9. Sample gas should be delivered to the instrument at atmospheric pressure.

10. CO is a highly poisonous gas. Long term exposure can cause problems with motor coordination and mental acuity. It is strongly recommended that all agencies have material safety data sheets (MSDS) at all locations where CO cylinders are stored or used. MSDS can be obtained from the DOT or from your vendor.
11. It is possible (and practical) to blend other compounds with CO. If this is the case, it is recommended that MSDS for all compounds be made available to all staff that use and handle the cylinders.
12. Shipping of cylinders is governed by the DOT. Contact the DOT or your local courier about the proper procedures and materials needed to ship high pressure cylinders.

## **6 INTERFERENCES**

Interferences are physical or chemical entities that cause measurements to be higher (positive) or lower (negative) than they would be without the entity. Studies have shown conclusively that NDIR analyzers have interference from water vapor. Water absorbs very strongly across several bands of IR spectra. Water vapor interference occurs because it absorbs light in the IR region at 3.1, 5.0 to 5.5 and 7.1 to 10.0  $\mu\text{m}$ . As a result, there is a quenching effect on the absorption of infrared light by CO. The CO analyzer is equipped with a permeation dryer, which effectively removes all water and water vapor. The dryer should be routinely checked for leaks but is not otherwise user serviceable.

Carbon dioxide ( $\text{CO}_2$ ) absorbs in the IR spectrum at wavelengths of 2.7, 5.2, and 8.0 to 12.0  $\mu\text{m}$ . This is very close to the regions that CO absorbs within as well. Because atmospheric  $\text{CO}_2$  is much higher in concentration than CO, this UV spectral range must be avoided. To prevent light in this spectral region, the CO analyzer has a band pass filter that blocks these wavelengths.

In order to measure in the ppb range, it is important for the detector to be operated at a very stable temperature. To obtain a stable baseline, the temperature of the detector and optical bench must be maintained within  $\pm 1.0$  degree Celsius ( $^{\circ}\text{C}$ ) of the set value.

## **7 PERSONNEL QUALIFICATIONS**

General Personnel Qualifications are discussed in the CDPHE/APCD/TSP QAPP.

## **8 APPARATUS AND MATERIALS**

### **8.1 Monitoring Equipment**

#### **8.1.1 Analyzers**

##### **8.1.1.1 Thermo Model 48i-TLE (Trace)**

The APCD uses the Thermo 48i-TLE trace level analyzers which are based on the same design and theory of operation of the 48C, but have been enhanced with upgraded or additional hardware and software to improve resolution and stability. The improvements to the 48C platform include a permeation dryer for the sample stream to reduce any moisture interference. The addition of a chamber that surrounds the correlation wheel and optical inlet to the sample cell which provides a continuous low flow purge of zero air that prevents dust build up on the correlation wheel and a CO interferent free environment from the IR source to the sample cell. Additional thermally controlled fans have been added to improve temperature stability and reduce signal drift induced by temperature instability. The 48i-TLE is also improved by the selection of best performing detectors from manufacturing, and process enhancement such as automatic self-zero adjustment at a selected time interval to compensate for any baseline drift. This auto-zero function is set to trigger every six hours in the APCD network. Processing power, firmware and data logging capacity are also enhanced (Thermo Scientific, 2007).

### **8.1.2 Instrument Shelter**

A shelter is required to protect the analyzer from precipitation and adverse weather conditions, maintain operating temperature, provides security and electrical power. The following are operation shelter temperature requirements for the SLAMS and NCore networks (US EPA, 2013) (US EPA, 2005).

SLAMs: 5-38 °C (20-30 °C preferred), evaluated on hourly averages at  $\leq \pm 2^\circ\text{C}$  Standard Deviation over 24 hours.

NCore: 20-30°C, evaluated on hourly averages, daily changes in hourly temperature should not exceed  $\pm 5^\circ\text{C}$  over a 24-hour period.

### **8.1.3 Test Gas System**

The APCD uses a span and precision system that uses direct non-diluted concentration, 8-10 ppm for span and 4 ppm for precision level, high pressure cylinders of carbon monoxide mixed in air which is delivered under controlled flow at atmospheric pressure to the analyzer. To provide the desired span/precision concentration a solenoid selects which gas cylinder feeds the system. The gases used are EPA protocol gas standards with NIST traceability. This system is enhanced by the use of the station data logger to control the span and precision process and data collection in the same manner if performed on site, remotely, or automatically. This standardizes the test process and reduces process errors. Data logger control of the tests and data averaging allows the test results to be reported by the data logger to a central computer. The exception to this method is for select trace level range CO analyzers that are challenged with 4 ppm span and 1ppm precision level by use of a gas dilution system. The dilution system generates concentrations of CO by diluting the concentration of an EPA Protocol NIST traceable compressed gas cylinder of higher concentration CO (w/balance in air) with zero air provided by a clean air supply. The zero air at the site is produced by pumping room air through a zero air supply with a catalytic oxidizer module for hydrocarbons. All gas must be delivered to the instrument at atmospheric pressure (Teledyne-API, 2009) (Teledyne-API, 2010).

### **8.1.4 Data Acquisition System**

The APCD employs three different models of onsite, data acquisition system equipment (DAS) in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, and the Agilaire 8872 data logger. The 8816 model is the oldest type of data logger in the network and is a predecessor to the 8832 and 8872 data loggers. The following are descriptions of these data loggers.

#### **ESC 8816 Data Logger**

The ESC Model 8816 Data System Controller is a microprocessor-based data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8816 is designed around an expansion bus that gives the user great flexibility in configuring the unit with a combination of analog and serial input and output (I/O) types.

For more details, refer to APCD's Datalogger SOP or the individual operator manuals (Environmental Systems Corporation, 2001).

#### **ESC 8832 Data Logger**

The ESC Model 8832 Data System Controller is a microprocessor-based data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8832 is designed around an expansion bus that gives the user great flexibility in configuring the unit with almost any combination of input and output types. It is the successor to the 8816 data logger and is more robust in numerous areas. Of significance is expanded memory, faster processing speeds, faster communication speeds, remote Ethernet communications and polling and Modbus enabled communications with peripheral devices.

For more details, refer to APCD's Datalogger SOP or the individual operator manuals (Environmental Systems Corporation, 2006).

### **Agilaire 8872 Data Logger**

The Model 8872 is a Windows-based data logger, a departure from the earlier 8816 / 8832 embedded systems designs. The 8872 includes a number of hardware and software features to ensure that the device matches the field reliability of the 8832, while offering the convenience of a Windows-based platform and integration with Agilaire's AirVision software.

The core of the 8872 is a fan-less PC, typically 2 GB of RAM. The device can be equipped with a 160 GB standard hard drive or, more commonly, a 64 GB solid state flash drive (SSD). For all digital versions of the 8872, the remainder of the enclosure simply provides convenient universal serial bus (USB), serial, and VGA I/O connections in a standard 3U rack mount enclosure, a form factor similar to the 8816 / 8832 family. However, the 8872 also supports traditional analog/discrete I/O via a variety of internal I/O modules and a protection / connector board to provide familiar detachable terminal block connections to the back. The layout of the connections is designed to make the unit easy to use as a 'drop in' replacement for an 8816 or 8832. (Agilaire, 2013)

For more details, refer to APCD's Datalogger SOP or the individual operator manuals.

#### **8.1.5 Wiring, Tubing and Fittings**

Teflon™ and borosilicate glass are inert materials that should be used exclusively throughout the ambient air intake system. It is recommended that Polytetrafluoroethylene (PTFE), Fluoroethylpropylene (FEP) Teflon™, perfluoroalkoxy (PFA) tubing be used. PTFE or FEP Teflon is the best choice for the connection between an intake manifold and the bulkhead fitting. PFA is a newer formulated Teflon than FEP. Like FEP, it is translucent which is also not machined, but unlike FEP, it can be molded into fittings. It has been accepted as equivalent to FEP Teflon but there is no real advantage to using PFA. The use of stainless steel tubing and fittings in the sample train is no longer permissible for CO analyzers. Examine the tubing and discard if particulate matter has collected on the tube's interior. All fittings and ferrules should be made of Teflon™. Connection wiring to the DAS should be shielded two-strand wire for analog communications and properly shielded RS-232 serial cable or Cat5 or higher Ethernet cable for digital communications.

#### **8.1.6 Reagents and Standards**

The Thermo 48i-TLE does not require any reagents since the instrument uses photometry to analyze for CO. All gas calibration and quality control concentrations for the CO method are obtained by direct injection or dynamic dilution of gas from cylinders whose contents must be traceable to NIST Standard Reference Material (SRM) gases via EPA Protocol procedures.

#### **8.1.7 Spare Parts and Incidental Supplies**

Thermo 48i-TLE: See Chapter 5 (Preventive Maintenance), Chapter 6 (Troubleshooting) and Chapter 7 (Servicing) in the Thermo "Model 48i Trace Level-Enhanced Instruction Manual Gas Filter Correlation CO Analyzer Part Number 102948-00 5Oct2011" operating manual for specific maintenance and replacement requirements.

### **8.2 Calibration Equipment**

#### **8.2.1 Calibration System**

See Figure 1.

- Dilution gas calibrator.

- The calibrator must have mass flow controllers for the dilution air (0.0 – 10.0 Lpm) and CO cal gas (0.0 – 0.1 Lpm) with these flows as the minimum full scale ranges.
- The calibrator must have a mixing chamber for dilution air and CO cal gas flows.
- Replaceable outlet particulate filter.
- High volume/pressure air pump.
- Permeation dryer, Indicating Silica gel or Calcium Carbonate.
- Catalytic oxidizer for the removal of hydrocarbons and carbon monoxide.

### 8.2.2 Accessories and Incidental Supplies

- External flow transfer standards capable of measuring flows of 10 - 10000 cc/min (Teledyne-API, 2009).
  - All flow transfer standards (such as a BIOS Definer) are to be certified against the APCD's Laboratory Flow Standard, which is certified at a regular interval by the manufacturer against references traceable to an NIST standard (Mesa Laboratories, MK01-26 Rev H).
- Digital thermometer measuring to tenths of a degree Celsius. This field transfer standard should be verified quarterly against an in-house mercury thermometer that is traceable by the manufacturer to a NIST standard.
- Hand held barometer measuring to tenths of an inch Hg. This field transfer standard should be verified quarterly against the in-house digital barometer standard that is traceable by the manufacturer to a NIST standard, and adjusted as needed
- Digital voltmeter (DVM) with a 0 - 1 volt range. It is annually verified against the in-house voltage standard, which has NIST traceability.
- Connecting lines made of 1/4" OD Teflon.
- Teflon™ is an inert material that should be used exclusively throughout the calibration system. It is recommended that Polytetrafluoroethylene (PTFE), Fluoroethylpropylene (FEP) Teflon™ or Perfluoroalkoxy (PFA) tubing be used.
- Calibration sheet (Figure 3).
- Thermo model 48i-TLE manual (Thermo Scientific, 2007). Each CO station must have a permanent copy.

### 8.2.3 Reagents and Standards

Certified CO calibration gas cylinder bottle are traceable to a NIST standard via EPA Protocol 2. Pre-dilution concentrations used are usually approximately 300 or 1000 ppm in a balance of CO<sub>2</sub> and air.

## 9 CALIBRATION

### 9.1 Introduction and Summary

The calibration of a gaseous analyzer centers on introducing known concentrations of a pollutant to the analyzer and adjusting the analyzer so that its readings accurately represent those concentrations (US EPA, 1990). An overview of the calibration process is given below.

1. Site Inspection Summary (section 9.2):
  - a. General inspection of the station shelter.
  - b. General inspection of all measurement and recording instruments, along with the CO analyzer, to see if they are working properly.
  - c. Minor maintenance on the shelter or instruments if required and within the scope of the calibration specialist's resources. If any of the analyzer operational parameters are out of specification or nearing being out of specification from the station log sheet target values (Figure 6), the calibration should be halted so repairs and/or major maintenance can be performed prior to calibration.
2. Calibration Procedure Summary (Section 9.3):
  - a. A pre-calibration station span, precision and zero routine is run (section 9.3.2).
  - b. A two point pre-calibration audit is run using the calibration equipment at the precision and zero levels (section 9.3.3.1, Pre-Calibration Audit Procedure).
  - c. Performance of any minor maintenance if required and within the scope of the calibration specialist's resources. If major repairs are needed, the calibration should be halted so repairs and/or major maintenance can be performed prior to calibration.
  - d. Adjustment of the analyzer's responses so that they accurately reflect introduced known concentrations of CO (section 9.3.3.2, Calibration Adjustment).
  - e. Introduction of five CO concentrations plus zero air in order to characterize the calibrated CO analyzer's response curve.
  - f. Determination of the automated zero, span, and precision values.
3. Calculation, recording, and reporting of results. A detailed description of this procedure is presented below in Sections **Error! Reference source not found.** and 9.4.

### 9.2 Site Inspection

A site inspection is conducted every time a calibration specialist goes to a monitoring station to calibrate, audit, or perform any other kind of calibration unit operation.

The inspection routine includes the following actions:

1. Check that any water drop (if present), and sample lines are not dirty or show condensation.
2. Check that all monitors' operational parameters such as pressure, temperature, and sample flow look normal compared to the values recorded on their calibration stickers and station log sheets. Refer to

an analyzer's manual and station CO log sheet for allowable ranges for each of its diagnostic parameters. If any parameter on any analyzer is out of bounds then the monitoring technician should be notified that day. Maintenance should be performed by the calibration specialist if possible, and a calibration on the analyzer may be necessary.

3. Check that the station temperature high/low readings are within a range of 20 - 30 °C (68 - 86°F).
4. Check the station logs for non-routine actions.
5. Check that all gaseous analyzers and meteorological (met) sensors appear to be reading ambient values that are reasonable given outside conditions and past readings for that individual station. This is done by looking at the real time data logger readings. For the gaseous analyzers, make sure their front panel readings match those on the data logger. For specifics on using the data logger refer to data logger SOP appendix in this QAPP document.
6. If you need to access the data logger functions through one or more login codes (codes are required) and aren't sure if you're authorized for access, call either the supervisor or the monitoring technician to see if you are. If you know that you are authorized, but have forgotten the login codes, call key contact personnel within the Technical Services Program (TSP) for the codes. Key contact people within the GMM work groups are posted within every monitoring station.
7. Check visually that the meteorological tower's instrument crossbar is properly aligned. Check that the meteorological sensors aren't damaged and are moving without binding.
8. Check that the station structure is not damaged.
9. Check that all analyzer clocks and digital chart recorder clocks agree with the data logger and that they are showing the proper time (10.6.9). If any change is made to a device then log the action, date and calibration specialist's initials in the relevant log. For changes to the data logger clock consult first with GMM supervisory or data management staff.
10. Check that all pumps are running smoothly and are not overly hot to the touch. Check also that exhaust lines between the pump and the analyzer are not rubbing on the pump, which can lead to a hole being worn in the line.
11. Perform a leak check on the analyzer that is to be calibrated.

If anything is found out of the ordinary it is recorded on the relevant log sheet, along with the date and the calibration specialist's initials. The site operator (or work lead or supervisor of the GMM unit if that person is not available) is notified that day. Maintenance should be performed if appropriate and within the scope of the calibration specialist's resources.

### **9.3 Calibration Procedure**

#### **9.3.1 Calibration Train Setup**

The zero air source and the compressed gas cylinder are attached to the dilution calibrator, which is used to mix various levels of carbon monoxide. These concentrations are then measured by the analyzer under calibration (Figure 1).

1. Nominally the zero air path (Figure 2) goes through the TAPI 701H zero air supply and on to the dilution calibrator. If the zero air supply does not have its own CO scrubber, attach a separate catalytic oxidizer in the train between the zero air pack and the calibrator. If a commercial system is not used, zero air for the calibration train may be provided as follows:

- a. First, a high volume/pressure air pump, particulate filter and pressure regulator with a line going to:
  - b. The dryer, a clear plastic cylinder filled with indicating desiccant such as silica gel, with an input and output at either end. The cylinder must be placed on end so that no channeling occurs. Either end may be the input or output. From there a line leads to:
  - c. Scrubber canisters which may contain charcoal and/or Purafil which are not critical for CO but will remove non-hydrocarbon pollutants and reduce reactants from entering the next stage which is:
  - d. The catalytic oxidizer (catox). This is where CO and other hydrocarbons are oxidized. Caution: catox units use very high temperatures. Care must be used in operating these properly so that no injury to the calibration specialist or catalytic oxidizer occurs. See the appropriate manual for the catox. (NOTE: Make sure that it does not exceed its recommended temperature and is allowed to properly cool at the end of the calibration in order to prevent damage to its catalysts.) From there a line leads to:
  - e. The zero air input of the dilution calibrator. The APCD currently is using TAPI 700 series gas dilution systems which use certified mass flow controllers (MFC) under computer control to provide known concentrations of a pollutant by ratio mixing of zero air and source gas.
2. Connect the bottled CO calibration gas regulator supply line directly to the designated cal gas input of the dilution calibrator. Adjust delivery pressure to about 20 to 30 PSI.
  3. Connect a short Teflon line to the output port of the dilution calibrator that will be connected to the supply tee.
  4. At the free end of this line connect a tee at one of the tee arms. This is the supply tee.
  5. On the other arm of the tee connect an open-ended line. This line should be at least thirty centimeters long, but not longer than 75 centimeters. This is the excess flow line.
  6. The calibration train is assembled and all elements are turned on. While the cal train is warming up and stabilizing, the station calibration zero, span and precision routine can be performed. In the case of using a Sabio 2050 external catalytic oxidizer, it takes about 10 minutes for it to stabilize at the required 100° C (for temperature set points, particularly when calibrating hydrocarbons, check with the manual or manufacturer).

**WARNING:** There must be airflow through the catox when it is turned on or the catalyst elements will be damaged. When the catox is no longer needed, turn off the heater, but keep zero air at full flow going through it until catox temperature reaches <30°C.

### 9.3.2 Pre-calibration Zero, Span, and Precision Routine

This routine is done before there is adjustment to the analyzer to help correlate the preceding automatic zeros and spans (z/s) and precisions (p) with the pre-calibration audit responses. It is also done at the end of the calibration procedure to generate new official z/s/p values for the following sampling period until the next calibration. In practice these routines are started just before and after any calibration / audit to allow time to set up or tear down the calibration equipment while they run their course.

If the analyzer is communicating with the data logger over an analog connection, connect a digital volt meter (DVM) or digital chart recorder to the analog output of the monitor or the analog input of the data logger according to ease of accessibility. This step should not be performed if the analyzer is communicating with the data logger

over a digital connection (GSI or Modbus). Readings on the data logger are taken from the CO channel (and not, for example, from the CO\_RAW channel). The CO channel is a calculation of CO\_RAW-K1 where K1 is the result of the last successful zero phase, thereby zero adjusting the real-time data.

1. Take the CO analyzer offline.
2. Put the analyzer into zero mode. Along with manual spans and precisions this can be done through the front panel of the analyzer or through the data logger. Refer to analyzer and data logger manuals for specifics on how to do this.
3. To emulate the midnight zero process the analyzer is allowed to stabilize for five minutes. Then during the second five minutes the calibration specialist takes readings as the data logger does during the automatic zero. However, instead of taking the average of many readings over the second five minutes, it is usual just to take one reading from each of the displays if the readings are constant, varying less than  $\pm 0.1$  ppm over five minutes. This taking of one reading per display is done for all of the points introduced during the calibration procedure. If the readings for all points taken in the calibration vary  $>\pm 0.1$  ppm within a five minute time frame, then a taking of ten readings evenly spaced over five minutes is required with the average being recorded. A note in the analyzer log and calibration sheet comments section should flag the instability. Take readings from:
  - a. The data logger concentration value. For analyzers with a CO Raw channel, be sure to use the CO channel instead. This is the most important value as these are the values that ultimately get reported to AQS
  - b. The front panel display.
  - c. A Digital Volt Meter (DVM) reading of the analog output line.
  - d. The data logger voltage reading.
  - e. The site chart recorder reading if present.

Record all readings on the calibration sheet. This is done for all of the points introduced during the calibration procedure. Make sure all voltage readings and concentration readings agree with each other.

4. Take the analyzer out of zero mode.
5. Put the analyzer into span mode.
6. Let stabilize for five minutes. Within the second five minutes take the readings and record.
7. Zero-correct the data logger span results.

$$\text{span value} - \text{zero value} = \text{zero corrected span (zcs)}$$

8. Calculate the percentage relative error (%RE) of the span and record on the calibration sheet.

#### Equation 2. Percent Relative Error

$$\frac{\text{zcs} - \text{span bottle value}^*}{\text{span bottle value}^*} * 100\% = \%RE$$

\*Use the EPA Protocol 2 measured sticker value on the station test gas bottles if the test gas is used directly and not diluted by an in-station dilution calibrator. Note: it is usual for a positive 2 – 3 %RE at the

span level if the analyzer is properly calibrated at the zero and precision levels. If a dilution calibrator is used to span the analyzer, use the dilution calibrator output concentration reading in place of the span bottle value.

9. Take the analyzer out of span mode.
10. Put the analyzer into precision mode.
11. Take the readings (just as in span mode). Calculate the %RE of the zero corrected precision (Equation 2), and record. Use the EPA Protocol 2 measured sticker value on the bottle. If a dilution calibrator is used for precisions, use its test gas output reading on the display in place of the precision bottle value.
12. Return analyzer to sample mode.

These points may also be run using the built-in routines in the data logger which will store the results in the site's calibration report. If the full built-in auto span, precisions and zeros are run to their end, K1, a math constant used for zero adjusting CO from CO Raw, will be updated. This is allowable and makes no great impact on the calibration procedure, but the calibration specialist must be aware of this at the time. The K1 constant in any case will be set to 0 later by the calibration specialist during this calibration. Just follow the same data collection process for the various displays/devices.

### **9.3.3 Pre-Calibration Audit, Calibration Adjustment, and Post-Calibration Assessment**

#### **9.3.3.1 Pre-Calibration Assessment Procedure**

##### Introduction

From the transfer standard calibrator set up introduce zero and precision levels test gas to the analyzer. Calculate %RE for the zero corrected precision level results. If this exceeds +/- 10 %RE, follow with a full five point plus zero calibration assessment audit (the same as a post-calibration assessment in method below) before any adjustment is made to the analyzer. This assessment audit is the same as described below in section 9.3.3.3 Post-Calibration Assessment. This is to characterize the out-of-spec condition fully, and the information will be used during data validation.

If the analyzer fails the pre-calibration assessment audit then repairs and calibration of the instrument are done as soon as possible after the audit. If the repairs required are beyond the resources of the calibration specialist then the monitoring technician for that station is notified immediately. Proceed to the calibration adjustment procedure in Section 9.3.3.2 if the pre-calibration audit results less than +/- 10 %RE. Failed pre-calibration assessment audits require an electronic message in the data logger that will to be use for data validation purposes. The procedure for performing the pre-calibration audit is given below.

##### Procedure

1. If a TAPI 700x type calibrator with certified MFCs is used then simply request the desired CO concentration level or ZERO point needed. Refer to the calibrator's operating manual for procedures on how to generate manual concentrations from the calibrator (Teledyne-API, 2009). For a "dumb" calibrator with certified MFCs use the calibration curve for the specific MFC to set the flow rate required using the formula in step 8 below to calculate the desired flows and concentration.
2. Let the dilution airflow in the calibrator stabilize. If taking flow measurements and the flow meter used does not automatically apply temperature and pressure compensation then these will need to be calculated separately per the next step #4. Let the thermometer and barometer equilibrate. This should usually take less than five minutes.

3. Measure the dilution airflow with the flow meter:
  - a. Make sure that the CO cal gas is not mixing with the dilution air. Connect the input of the external flow meter to the exit port of the calibrator before the supply tee.
  - b. Take at least two temperature readings bracketing in time the flow measurement period and one barometer reading. Measure ten readings of the dilution airflow through the external flow meter. Average the ten readings and record on the calibration sheet. This is the raw dilution airflow rate.
  - c. If the flow meter does not do STP correction or it is in “Volumetric” mode which does not apply correction then use this formula for a dimensionless correction factor,

**Equation 3. STP Correction Factor**

$$\frac{BP * 298.2}{29.92 * (273.2 + T)} = c$$

where

BP = barometric pressure to nearest hundredth of an inch of Hg.

T = air temperature in degrees C to nearest tenth of a degree.

cf = unitless correction factor to STP.

298.2 = Kelvin degrees equivalent for a 25 degree C temperature standard (273.2 + 25). A temp standard of 0 degree C = 273.2

29.92 = inches of Hg at one atmosphere.

- d. Calculate c.f. and multiply the raw flow rate by this to get the dilution flow rate at STP of 25 degrees C and 29.92" Hg. If the MFC manufacturer uses a different STP baseline then use those parameters in the correction. TAPI for example, uses an STP of 1atmosphere and 0 degrees C so the formula would use 273.2 instead of 298.2
  - e. Record all calculations and results on the calibration sheet.
4. Disconnect the analyzer sample line from the manifold, if present. Make sure to plug up the hole on the manifold if other analyzers are still sampling from it.
  5. If a through-the-probe z/s/p supply is set up for the CO analyzer, disconnect the z/s/p supply line at the end of the last valve solenoid.
  6. If no manifold or through-the-probe z/s/p system is present, disconnect the sample inlet line at the back of the CO analyzer and attach to the supply tee's trunk. Reconnect the calibrator's output port to the tee's arm through the supply line. The excess flow from the end of the excess line should be about 10 to 50% of analyzer flow for all test points. At this time only zero air should be going into the analyzer.
  7. Allow at least five minutes after the analyzer has stabilized. Record the results on the calibration sheet. This is the pre-calibration zero air concentration reading.
  8. Generate a CO flow that will cause a 10 to 20 % full scale of reading (the precision level) when diluted (see step 1 above). Measure and correct the measured flow to STP as done with the zero air. The unmixed CO cal gas has a separate port on the calibrator for measuring its flow, (refer to the appropriate calibrator manual).

9. If using a manually flow measured calibrator (this step not necessary for an automatic calibrator with certified mass flow controllers) calculate the CO concentration in ppm (true [CO]) from mixing this cal gas flow with the dilution flow.
  - a. Use the formula below and the TAPI 700 output readings for gas and zero air dilution flows to calculate the TAPI 700 is working correctly, and that none of the MFC usage parameters have been exceeded. The MCF's should not be used below 10% of full scale or above 90% of full scale for older (99% for newer) MFCs.

#### Equation 4. True CO Concentration

$$\frac{CONC * Fg}{(Fd + Fg)} = true[CO]$$

where:

CONC. = concentration of cylinder calibration gas in ppm.

Fg = flow rate of calibration gas in STP cc/min.

Fd = flow rate of dilution zero air in STP cc/min.

- b. Calculate the concentration of the diluted calibration gas (true [CO]) in ppm.
10. Mix the CO cal gas and dilution air and let the analyzer sample it. Allow at least five minutes after a stable response from the analyzer is achieved. Record the results on the calibration sheet. Zero correct the results.

Calculate the relative error of the analyzer's response

#### Equation 5. Percent Relative Error

$$\frac{Analyzer\ Reading/(DAS) - true[CO]}{true[CO]} * 100\% = \%RE$$

11. If the precision level error is < +/- 10% RE a full assessment audit is not required, proceed to 9.3.3.2. If it equals or exceeds +/-10% RE, follow with a full four point plus zero calibration assessment audit (the same as a post-calibration assessment in section 9.3.3.3 below) before any adjustment or repairs are made to the analyzer. This is to characterize the out-of-spec condition fully, and the information will be used during data validation. Additionally, if the assessment fails, documentation of this failure in a Message to Central is required as described in Section 9.3.3.3 Step 11.

### 9.3.3.2 Calibration Adjustment Procedure

#### Introduction

After the pre-calibration audit, the analyzer is adjusted (calibrated) at the zero and precision levels so that the analyzer most closely matches the known concentrations produced by the calibration system at the zero and precision levels. After this is done, a five level plus zero multipoint post-calibration assessment (Section 9.3.3.3) is reintroduced to characterize the analyzer response over the entire measurement range. The calibration points are generated by diluting a higher concentration of CO from a NIST-traceable calibration gas to a target concentration. The recommended ranges for the multi-point calibration points are detailed in Table 1. As each calibration point is generated, the responses shown by the data logger should be compared to the calculated value.

**Table 1. Calibration Ranges for Carbon Monoxide Analyzers**

CO Calibration Ranges		
	<i>(Trace)Range</i>	<i>(Standard) Range</i>
<b>Units</b>	Parts per million (ppm)	Parts per million (ppm)
<b>Calibration scale</b>	0 to 5.0 ppm	0 to 10.0 ppm
<b>Compressed gas cylinder</b>	60-1000 ppm*	100-2500 ppm*
* Based on calibrator mfc ranges: gas1 = 50ml/min, gas2 = 100 ml/min, dil = 10 or 20 l/min		
Calibration points		
<b>Level 1</b>	4.0 - 5.0 ppm	8.0 - 10.0 ppm
<b>Level 2</b>	2.5 – 3.5 ppm	5.0 - 7.5 ppm
<b>Level 3</b>	1.5 – 2.5 ppm	3.0 - 4.5 ppm
<b>Level 4</b>	0.5 – 1.0 ppm	1.0-2.0 ppm
<b>Level 5 - zero</b>	0 - 0.01 ppm	0 - 0.5 ppm

Level 4 is the accepted precision level that is used to adjust the calibration of the analyzer with as little error as possible (along with Level 5, or the zero level). The procedure for performing the calibration adjustment is given below.

#### Procedure

1. If the precision level error is  $< \pm 10\%$  full scale RE and a full 5 point assessment is not required, leak check the analyzer.
2. Send zero air to the analyzer again. Let the analyzer stabilize. Go to the Calibration Menu. Select CO BACKGROUND and then ENTER.
3. Send 10 to 20% full scale of CO to the analyzer. Let the instrument stabilize for at least five minutes.
4. From the Calibration Menu, choose CO COEFFICIENT. Dial in the true CO concentration being introduced to the analyzer. Press ENTER.
5. Send zero air again to the analyzer. Let it stabilize for at least five minutes. Readjust the zero display value if necessary and repeat steps STEP NUMBERS and then come back to this step. Several jumps between the zero air and the 10 to 20 % full scale level, along with calibration adjustments, may be required. After all adjustments are done, let the analyzer stabilize on a cal zero input.

#### **9.3.3.3 Post-Calibration Assessment Procedure**

##### Introduction

The post-calibration assessment challenges the analyzer with five different test gas concentrations levels plus a zero to evaluate the accuracy of the new calibration. The assessment begins with a zero point followed by points at  $< 20\%$  (Level 4 - precision),  $> 80\%$  (Level 1 - span),  $\sim 60\%$  (Level 2), and  $\sim 40\%$  (Level 3). Results for these tests are used to evaluate the relative error at full scale. Concentration levels are generated as described in the pre-calibration

assessment (**Error! Reference source not found.**). The procedure for performing the post-calibration assessment is given below.

Procedure:

1. After the cal zero input is stable, record the results on the calibration sheet.
2. Send the 10 to 20% full scale gas to the analyzer. Let it stabilize for at least five minutes. Record the results on the calibration sheet.
3. Introduce a Level 1 concentration (greater than 80% full scale to the analyzer). Let it stabilize for at least five minutes. Record results on the calibration sheet.
4. Measure and generate three more CO concentrations that come in at approximately 70, 50, and 30% of full range. Introduce to the analyzer as above. Record the results on the calibration sheet.
5. Send a final zero air to the analyzer and record the results. Calculate a least-squares linear regression between the known CO concentrations (including the zero point) as the ordinate and the zero corrected analyzer responses as the abscissa. Record slope, intercept, and correlation coefficient on the calibration sheet. Also calculate, using this response curve, a %REFS for a calibrated analyzer response given a known introduced concentration of exactly 90% of the full measurement range of the analyzer.
6. The criteria for a successful calibration is where all non-zero test points after the calibration adjustment show a  $\pm 10\%$  full scale error compared to the final best fit regression calibration line. The precision level should be as close to 0% error as possible. Due to the nature of the analyzer, this often results in upper range test points approaching the criteria limit and this is considered normal. If the post-calibration assessment begins to show a failure at any point, and repeating previous analyzer adjustments do not solve the problem, then maintenance is probably needed on the analyzer.

**Equation 6. Relative Error at Full Scale**

$$\frac{[(90\% \text{ full scale} * m) + i] - 90\% \text{ full scale}}{90\% \text{ full scale}} * 100 = \%REFS$$

where:

m = slope of response curve.

i = intercept of response curve.

90% full scale = 20 ppm (5 ppm at La Casa station).

%REFS = Relative Error at Full Scale

7. Reattach the analyzer sample line so that it reads ambient.
8. Do another on-site system zero, span and precision routine like the one done before the calibration (Section 9.3.2). Record results on the calibration sheet and on the calibration sticker. These are the new midnight z/s/p values.
9. Record analyzer parameters, especially the new analyzer calibration settings, from the front panel display on the calibration sticker and sheet.
10. Enable the analyzer on the data logger. Record the MST time the instrument was brought back on line on the calibration sheet and on the station CO log. Put the calibration sticker on a surface near the analyzer so that it is easily read.

11. On the data logger message window to Central type and send:

C:CO, Z=aaa, S=bbb (bot xxx), P=ccc (bot yyy), ddd <enter> where:

aaa = data logger CO zero reading in ppm.  
bbb = data logger CO uncorrected span reading in ppm.  
xxx = span bottle concentration if not diluted.  
ccc = data logger CO uncorrected precision reading in ppm.  
yyy = precision bottle concentration if not diluted.  
ddd = calibration specialist's initials.

This is a message through the data logger to the GMM unit worker responsible for z/s/p records, reporting the new z/s/p results generated after the calibration (see Section 0).

In the event of a failed precalibration audit or assessment, a separate message is sent to Central in the form of

“CO CAL FAILED AUDIT”,

(in all CAPS) followed by a general description in regular text and the calibrator's initials. This is to highlight important cal/audit information for the purposes of data validation.

12. Record analyzer parameters and calibration and maintenance actions on the station CO log.

#### **9.4 Reporting and Filing of Calibration Results**

The results of a calibration or assessment check are recorded and reported by the calibration specialist as follows (this is a summary; some of these actions have already been mentioned):

1. Record analyzer parameters, calibration and maintenance actions, cal date, beginning/ending disabled time and calibration specialist's initials on the station logs.
2. Record the calibration and check points, linear regression results, cal date and calibration specialist's initials on the calibration report form (Figure 4) and in the Calibrations database (Figure 4), along with relevant comments. If possible and if the required computer and software are available download the data stored in the analyzer's own internal data logger.
3. Any unusual thing seen at a station, even if rectified by the calibration specialist, is reported that day to the field technician and recorded in the station logs
4. Record uncorrected data logger and chart z/s/p results, analyzer calibration settings, cal date and calibration specialist's initials on the station sticker.
5. Put the calibration sheet with all of the calibration information, beginning/ending disabled time, cal date and calibration specialist's initials into the specially designated ring binder at the home office. Each year of calibrations and assessment checks has its own binder. The most recent four to five years of calibration and assessment audit sheets are kept at the home office. Older binders are put into permanent storage.
6. Calibration records in the Calibrations database, located on local PCs, are uploaded to the J:Drive Master Calibration database monthly for centralized archiving.

## 10 OPERATION AND MAINTENANCE

### 10.1 Introduction and Description of Monitoring

The CDPHE TSP uses exclusively Thermo Scientific 48i-TLE carbon monoxide instrument.

The operators manual gives the operational details and requirements for this analyzer. The Thermo 48i-TLE manufacturer's instruction manual is complete and cover all necessary procedures and controls for successful operation except for the operations and maintenance of the Carulite zero air scrubber. A separate addendum for the Carulite scrubber is provided at the end of this document (

). This CO manual, as well as this SOP, are available at each CO site, with each manual accompanying its respective analyzer. These manuals are also available at the central offices of TSP. For the ESC AQM-8816, AQM-8832 and Agilaire 8872 data loggers, the manufacturer's technical manuals provides all operating instructions and system keyboard command descriptions. These data logger manuals are also available at each site, with each manual accompanying its respective analyzer, and at the central offices of TSP. Refer to these manuals regarding any aspect of operation of these systems.

Each continuous CO monitoring site is assigned to a specific TSP employee qualified by formal training, experience, TSP on-the-job training, and courses offered by EPA. This employee is responsible for all aspects of assigned site monitoring operation, including but not limited to maintenance, repair, documentation updates, logs, etc. In addition to keeping sites operational with a minimal downtime, any of the senior level instrument specialists may be called upon to accept the responsibility for training of new TSP employees and/or contracted operators.

In the current monitoring network all of the gaseous analyzers have some capacity to store data. Digital chart recorders provide a backup of data by storing the data on memory cartridges. As a result TSP considers the data acquired by the site data logger system when properly validated to be the primary data source with the digital chart recorders as an emergency data backup and verification system for the older CO analyzers which is only one of several data validation and troubleshooting tools.

Data quality and validity determinations are based partly on quality control data produced from onsite test systems. An "Onsite Test System" is a system of control hardware, software and standards at the monitoring location that is capable of accurately generating and introducing known concentrations of test gas to a monitoring system. These onsite test systems are capable of performing "Performance Tests" and "QC Precision Tests". The different tests are used to assess and document different aspects of system performance and data quality. A "Performance Test" is an automated or manual evaluation of a monitoring system's performance and is achieved through the introduction of a known concentration of test gas, typically at the span or precision level, and is not intended to be submitted to EPA for determinations of bias. A "Quality Control (QC) Test" is a manual check initiated every two weeks by APCD staff, who can attest to its validity, and is achieved through the introduction of a known concentration of test gas at the precision level and whose purpose is to be submitted to EPA for determination of bias. "Performance Tests" and "QC Tests" are inherently different and are initiated by different sequences within the data logger. These sequences consist of phases that can vary in concentration, order, and duration.

For CO, test concentrations are listed in Table 2. CO Test Targets **Error! Reference source not found..**

**Table 2. CO Test Targets**

	<b>Span</b>	<b>Precision</b>
<b>Non-diluted EPA protocol</b>	8 – 10 ppm	4 ppm
<b>Diluted EPA protocol</b>	4 ppm	1 ppm

The APCD uses three different types of onsite test systems within the air monitoring network, two of which are used in the carbon monoxide air monitoring network. Explanations of the onsite test systems are as follow.

#### Non-diluted EPA protocol test gas system

In this system the test gas is connected directly to the analyzer.

The onsite test gas delivery system introduces known test gas concentrations to select Thermo 48i-TLE analyzers in the network by directly introducing test gases of known concentration from compressed gas bottles into the sample stream at atmospheric pressure, normally by venting through the sample inlet. These test gases are considered transfer standards which meet the EPA protocol standard of certification and NIST traceability. To provide the desired span/precision concentration a solenoid selects which gas cylinder feeds the system. This system is enhanced by the use of the station data logger to control the span and precision process and data collection in the same manner if performed on site, remotely, or automatically. This standardizes the test process, reducing process errors. Data logger control of the tests and data averaging allows the tests results to be collected and reported by the central computer.

#### Diluted EPA protocol test gas system

The test gas and a zero-air source are connected to a dynamic dilution calibrator, which then connects to the analyzer.

The onsite test system introduces known test gas concentrations to select Thermo 48i-TLE analyzers by blending known concentrations of test gases with diluent air having zero concentration of the test analyte. A bottle of high concentration test gas and a source of diluent gas are connected to a Teledyne model 700x dilution calibrator containing two or more calibrated mass flow controllers. The dilution calibrator can then be instructed to generate calculated concentrations which are fed to a solenoid manifold configured to allow the gas to the sample inlet of the analyzer at atmospheric pressure. The combination of the NIST traceable test gas and the calibrated mass flow controllers provides sufficient confidence in the calculated concentrations. This system is ideal for monitoring stations with span and precision requirements that are not otherwise achievable by the non-diluted EPA protocol test gas system, such as when a target concentration is lower than available test gas bottle concentrations. As with the non-diluted EPA protocol system, this system is enhanced by the use of the station data logger to control the span and precision process and data collection in the same manner if performed on site, remotely, or automatically. This standardizes the test process, reducing process errors. Data logger control of the tests and data averaging allows the tests results to be collected and reported by the central computer.

## **10.2 Equipment and Supplies**

For a complete listing of supplies and equipment please see Section 8 of this standard operating procedure.

## **10.3 Logs and Forms**

All actions at the site, scheduled and non-scheduled, are logged on forms. These forms are collected monthly, reviewed and filed together in monthly folders in a maintenance files cabinet. Three complete calendar years of

forms are readily available on site. The intent of these forms is to be able to recreate events and actions taken well after the fact. Examples of these forms can be found at the end of this subsection.

The forms in routine use are:

1. MONTHLY STATION ACTIVITIES LOG (**Error! Reference source not found.**)
2. MONTHLY CO ACTIVITIES LOG (**Error! Reference source not found.**)
3. MONTHLY MAINTENANCE REPORT FORM (**Error! Reference source not found.**)
4. CO ZERO/SPAN/PRECISION CONTROL CHART (**Error! Reference source not found.**)

#### **10.4 General Operations**

This section provides an overview of scheduled inspection and preventive maintenance procedures. To minimize downtime and ensure data quality, preventive maintenance is to be performed on all gaseous monitors in the network according to a schedule established by TSP, using the inspection criteria documented in this chapter. Below is a general summary of the types of maintenance check performed.

Data from each site is evaluated daily. There is a daily morning review of overnight Quality Control checks, data validity flags, data completeness, data representativeness, logger messages, and shelter environmental status to determine if an immediate site visit is needed. Data loggers are contacted as needed to evaluate and configure instrument systems.

The Weekly inspection is performed once each calendar week and as needed.

The Precision tests and Zero/Span cycles are automated and controlled by the data logger, but may be done manually at any time, and are required to be performed once every two weeks.

The Monthly inspection is performed at the beginning of each calendar month.

Upon completion of an inspection, log entries onto the MONTHLY STATION ACTIVITIES LOG, MONTHLY CO ACTIVITIES LOG, and into a “Message to Central” are required. Enter all tasks performed, any malfunctions, or other actions needed, discovered during the inspection.

All scheduled checks are minimum requirements. Individual site circumstances may dictate a more frequent preventative maintenance schedule. Monthly, quarterly, and semi-annual inspections are always conducted by TSP-approved staff that has the training or experience to reliably perform the required checks or maintenance.

By contract agreement, it is the responsibility of all contracted site operators to notify TSP of any unusual instrument/equipment performance, possible malfunction, or outright malfunction, and action taken, if any. TSP in turn will take the appropriate action as soon as workload and priorities permit. TSP maintenance personnel will summarize work performed in a “message to central” for all non-scheduled maintenance activities.

#### **10.5 Routine Preventative Maintenance and Scheduled Activities**

Preventive maintenance inspections and services should follow the recommended intervals by the EPA, the manufacturer, or as determined by actual experience. If preventive maintenance services are not being done according to the minimum guidelines of the manufacturer as set forth in this standard operating procedure, the TSP may jeopardize any claim to a manufacturer’s warranty and may jeopardize the validity of the data collected. The preventive maintenance inspections are scheduled to provide an opportunity to detect and repair damage or wear conditions before major repairs are necessary and the loss of data occurs. The documentation of these activities is essential for quality control tracking and for compliance with EPA’s Quality Systems methods. Site and analyzer log sheets along with “messages to central” are part of the official record and the documentation of maintenance or observations are to be written clearly and concisely and in accordance of good laboratory practices.

**Table 3. Routine Preventative Maintenance and Schedule Activities**

Procedure or Resource	Description
<b>Every Onsite Visit</b>	
	Check station for general condition and proper operation of heating, air conditioning, lighting, and sample pumps.
<b>10.6.2</b>	Check all analyzers for faults and operability. Verify that the data logger is working correctly and reported values match the analyzer display.
<b>Figure 2</b>	If equipped, observe the operating condition of zero air pack. Check for faults and short cycling.
	Remove trash when waste receptacles are full. Remove from shelter all odorous trash, such as leftover food and food packaging.
<b>10.6.10</b> Error! Reference source not found.	Leave a “message to central” and a site log entry summarizing purpose of visit and a summary of all maintenance performed
<b>Weekly Inspection / Maintenance</b>	
	Perform Every Onsite Visit inspections as defined above.
	Perform general housekeeping as necessary. Includes sweeping station as necessary. Dispose of trash as necessary. Clean up trash and remove weeds/vegetation from surrounding property.
<b>10.6.4</b> <b>Figure 5</b>	Note analyzer operational and diagnostic parameters on analyzer log sheets. <ul style="list-style-type: none"> <li>• Check results from previous night’s Performance Test and record ppm levels on Analyzer Log Sheet</li> <li>• Using the log sheet as guidance, record the analyzer calibration factors and analyzer diagnostic test parameters on analyzer log sheet.</li> </ul>
	Check CO readout, data chart trace (if equipped) and data logger CO readout for agreement. Verify agreement between devices is within $\pm 0.2$ ppm
<b>10.6.8</b>	Inspect and empty water drop out system, (if equipped) – note on analyzer log sheet if water found. If flask is removed, perform a leak check after reassembling the system.
	Enter notes and initial analyzer log sheet
<b>Figure 5</b>	Log all bottle gas supply pressures on station log sheet
<b>Figure 5</b>	Log station maximum & minimum temperatures on station log sheet and reset thermometer if available.
<b>Figure 5</b>	Enter notes and initial station log sheet
<b>10.6.10</b>	Leave a “message to central” summarizing purpose of visit and a summary of all maintenance performed

Procedure or Resource	Description
10.6.4	Check desiccant moisture content and replace if mostly pink
<b>Every Two Week Period</b>	
10.6.12	Perform Manual Quality Control Precision Test – Performed by APCD staff
<b>Monthly Inspection / Maintenance</b>	
	Perform Weekly Inspection/Maintenance as defined above.
	Check associated wiring, power cables, and plumbing (lines and fittings) for wear, damage and proper installation.
	Inspect analyzer fan filters and clean as necessary (if equipped).
10.6.9	Check analyzer time against a National Institute of Standards and Technology traceable time piece (i.e. cell phone) and adjust if ( $>\pm 1$ min) see analyzer manual or clock procedure. For changes to a data logger clock contact GMM supervisor or central PC staff first.
10.6.6	Check that the internal data acquisition program in the analyzer is operational.
10.6.3	Replace sample filter. Leak check the analyzer.
10.6.8	Perform leak check of test gas manifold solenoid/s (if equipped)
10.6.4	Perform baseline adjustment on non-auto adjusting analyzer if necessary (zero $> \pm 0.3$ ppm,)
<b>Figure 5</b> <b>Figure 6</b>	<p>Fill out new monthly station, analyzer, and calibrator (if equipped) log sheets for the upcoming month. Include the following key elements:</p> <ul style="list-style-type: none"> <li>Analyzer log sheet – site name, month, year, analyzer range and analyzer firmware, analyzer SN and other appropriate info required by log sheet</li> <li>Station log sheet - site name, month, year, bottle numbers, expiration date, concentration and pressure and other appropriate info required by log sheet</li> <li>Calibrator log sheet - site name, month, year, model, firmware, SN and other appropriate info required by log sheet</li> </ul>
	Upon completion of the Monthly Maintenance site visit, all previous months log sheets are collected and placed in the monthly forms data collection box within 2 business days of being collected.
<b>Quarterly Inspections / Maintenance</b>	
	None Required
<b>Six Month Inspections / Maintenance</b>	
	None Required
<b>Annual Inspections / Maintenance</b>	

Procedure or Resource	Description
	<p>Inspect and clean Heating, Ventilation and Air Conditioners (HVAC) units at site. Inspect for water access holes in the shelter, roof, and sides. Ensure AC unit is sealed against moisture on the shelter wall.</p> <ul style="list-style-type: none"> <li>• Perform maintenance in June or July</li> <li>• Replace or clean air conditioning and/or heater dust filters (if equipped)</li> <li>• Clean air conditioner coils</li> </ul>
<b>10.6.11</b>	In March or April, replace all sample inlet lines. (NOTE: blow-out all shielded long CO lines.) TTP calibration line maintenance.
<b>40 CFR Appendix B to part 136</b>	Perform Method Detection Limit (MDL) testing on NCore trace analyzers (reference CFR Method)

## 10.6 Maintenance Procedures

### 10.6.1 Disable/Enable Analyzer in Data Logger

ESC 8816/ 8832

*Disable analyzer data channel:*

From the top level menu, to disable a data channel from reporting to the data logger, the user must:

1. Choose menu options **CDM (C Configuration Menu > D Configure (Data) Channels > M Disable/Mark Channel Offline)** to view the list of available channels.
2. From the keyboard, using the down arrow button, scroll to the target channel name and hit the **Enter** or **Return** key. For CO or CO-Trace, select the respective choice. A limited list of channels that could be encountered includes:

Channel Option	Instrument or Analyzer / Channel
O3	Ozone Analyzer
O3 Cal	Ozone Calibrator
<b>CO</b>	<b>Carbon Monoxide Analyzer/Calibrator</b>
<b>CO_Trace</b>	<b>Carbon Monoxide Trace Level Analyzer/Calibrator</b>
NO	Nitrogen Oxide Analyzer
NO2	Nitrogen Oxide Analyzer
NOX	Nitrogen Oxide Analyzer
NOY	NOY Analyzer
SO2	Sulfur Dioxide Analyzer

get back to top level menu.

3. Next, hit the **Esc** (Escape) key twice to

4. Select menu option **DF (D Real-Time Display Menu > F Display Readings w/flags)** to ensure the proper machine was disabled. You should see the letter “D” within parenthesis and adjacent to the targeted channel indicating it has been disabled.

*Enable analyzer data channel:*

From the top level menu to enable the data channel to resume reporting to the data logger, the user must:

1. Choose menu options **CDE (C Configuration Menu > D Configure (Data) Channels > E Enable /Mark Channel Online)** to view the list of available channels.
2. From the keyboard, using the down arrow button, scroll to the target channel name, and hit the **Enter** or **Return** key.
3. If all machines/instruments and/or channels are already on line, the user will receive a message stating “No channels are offline” at the bottom left screen. Otherwise a list of channel names will appear.
4. Next, hit the **Esc** key twice to get back to the top level menu.
5. Select menu option **DF (D Real-Time Display Menu > F Display Readings w/flags)** to ensure the proper channel was enabled. You should see parenthesis adjacent to the targeted channel without the letter “D” inside indicating the machine/instrument channel is enabled and reporting to the data logger.

#### Agilaire 8872

##### *Disable analyzer data channel:*



1. After logging in to AirVision™, if the Site Node Logger Toolbox is not open, from the top level menu select the **Home** tab > **Utilities** > **Site Node Logger Toolbox** > then select the **Channels** tab.
2. Identify the channel to be disabled. At the right side of the form, under the “Disabled” heading, click on the row with the target channel name. This action will change the channel state from “False” to “True” indicating that it is now disabled and not reporting to the data logger.


##### *Enable analyzer data channel:*

1. After logging in to AirVision™, if the Site Node Logger Toolbox is not open, from the top level menu select the **Home** tab > **Utilities** > **Site Node Logger Toolbox** > then select the **Channels** tab.
2. Identify the channel name to be enabled. At the right side of the form, under the “Disabled” heading, click on the row with the target channel name. This action will change the channel state from “True” to “False” indicating that it is now enabled and will now report to the data logger.

## **10.6.2 Check Analyzer Calibrations Factors and Diagnostic Test Parameters Procedure**

### 48i-TLE Diagnostic Parameter Check Procedure

1. On the 48i-TLE front panel press the menu button. 
2. Scroll to the “Calibration Factors” with the down arrow and press enter button. 
3. Record the Bkg and Coeff on the site log form.
4. Press the menu button and scroll to “Diagnostics” and press enter.
5. Scroll to “Voltages” and press enter and scroll down to “Bias Voltage” and record on site log form.
6. Press the menu button and scroll to “Temps”, press enter and record Internal and bench temperature.
7. Press the menu button and scroll to “Pressure”, press enter and record on site log form.

8. Press the menu button and scroll to “Flow”, press enter and record on site log form.
9. Press the menu button and scroll to “Sample/Ref Ratio”, press enter and record on site log form.
10. Press the menu button and scroll to “AGC Intensity”, press enter and record on site log form.
11. Press the menu button and scroll to “Motor Speed”, press enter and record on site log form.
12. Press the run button  and record the clock time.

### **10.6.3 Filter Change Procedure**

1. Disable the CO channel on the data logger (10.6.1)
2. Remove the old filter from the filter housing off the back of the analyzer.
3. Place new 5um filter into the filter housing using tweezers to handle the filter.
4. Tighten the filter holder closed with the filter wrenches.
5. Inspect lines and fittings for seal.
6. Perform a leak check from the back of the analyzer (10.6.8).
7. Enable CO channel on data logger (10.6.1).

### **10.6.4 Desiccant Regeneration**

Desiccant changes from blue to pink as it absorbs water. When the desiccant container is mostly pink it should be swapped with dry desiccant. To regenerate desiccant (to dry it out) spread the granules thinly on a baking sheet and place in the oven in the laboratory for one hour at 210°C or 425°F. After one hour the desiccant should be stored in a sealed container at room temperature.

### **10.6.5 Baseline Adjust Procedure**

#### 48i-TLE Baseline Adjust

No routine baseline adjustment is required.

The 48i-TLE baseline is automatically internally adjusted. The 48i switches itself to a zero mode once every six hours, or four times daily, for five minutes and retains the average of the last two minutes. This average is then added to the background setting thereby adjusting the real-time CO reading. If the automatic system appears to be inoperable or malfunctioning, consult the manual and contact the site operator.

### **10.6.6 Internal Data Acquisition System Verification**

The purpose of this procedure is to ensure that the internal data logging capabilities of the analyzers are functioning properly. The procedure was taken from the Thermo CO analyzer manuals.

#### Thermo 48i CO Analyzer

To verify the internal data acquisition:

1. From the front panel Main Menu choose Instrument Controls > **Datalogging Settings**

```

DATALOGGING SETTINGS:
>SELECT SREC/LREC      SREC
VIEW LOGGED DATA
ERASE LOG
SELECT CONTENT
COMMIT CONTENT
RESET TO DEFAULT CONTENT
CONFIGURE DATALOGGING

RANGE  AVG  DIAGS  ALARM
  
```

2. Choose **VIEW LOGGED DATA** and press the down arrow to select **Date/Time**, press enter to accept

```

SELECT START POINT BY:
  SET TO: # OF RECS

  ↑↓ CHANGE      ← ACCEPT

RANGE  AVG  DIAGS  ALARM
  
```

3. Use the down arrow to scroll down to the date when the previous monthly was completed and press enter to accept


- a) Use the right arrow to pan through and verify

that data was captured in the internal memory

```

time    date    flags
10:01  06/20/05  FC0088900
10:02  06/20/05  FC0088900
10:03  06/20/05  FC0088900
10:04  06/20/05  FC0088900
  ↑↓ PGUP/DN    ↔ PAN L/R

RANGE  AVG  DIAGS  ALARM
  
```

- b) If no valid data is stored, then notify the appropriate personnel of the issue immediately.
4. Repeat the above steps and verify data acquisition for 5 other dates spanning the last month, ending with the current date
  5. Return to the run screen by pressing **RUN** 
  6. Fill out the required data acquisition verification entry on the Monthly log sheet

### 10.6.7 Bottle Change Procedure

1. Make note of the pressure left in the old bottle (psi).
2. Close the old gas bottle valve (clockwise turn).
3. Remove the gas line from the back of the dilution calibrator for NO, SO<sub>2</sub> and some CO; most CO cylinders are connected directly to the analyzer.

4. Inspect the line and fittings and replace as necessary.
5. Remove the two-stage regulator from the gas bottle.
6. For 660 CGA stainless regulators install a new Teflon washer onto the stem connection.
7. Connect the regulator to the new gas bottle.
8. If replacing the regulator, move the calibration gas line from the old to the new regulator.
9. Purge the regulator and line:
  - a. Using a quick connect with a push stop or your thumb over the end of the gas line, cap the gas line closed.
  - b. Back off the regulator pressure knob, and close the regulator valve.
  - c. Open the gas bottle valve until the bottle-side pressure gauge reads the bottle psi.
  - d. Close the gas bottle valve.
  - e. Open the regulator valve and the gas line until the regulator gauges go to zero psi.
  - f. Close the regulator valve and the gas line.
  - g. Repeat for a total of three times
10. Connect the gas line back to the appropriate gas port on the back of the dilution calibrator or CO analyzer, vent gas out of the line before tightening the fitting to ensure that gas is flowing through the line.
11. Set the regulator pressure to 30psi and ensure that the gas bottle valve and regulator valve are open, if connected to a calibrator verify that the gas pressure is within the required range.
12. Make note of the bottle change on the station log and record the new bottle number, gas type, concentration, expiration date and pressure.
13. Send two messages to central through the data logger (see 10.6.10)
  - a. The first message will consist of the designation of “old”, **old** bottle number, concentration(s), expiration date, and current bottle pressure.
  - b. Use the following format.
    - i. **Bottle Change Old FF40348 NOx 9.89 NO 9.74 07/29/16 600**
  - c. The second message will consist of the designation of “new”, **new** bottle number, concentration(s), expiration date, and current bottle pressure.
  - d. Use the following format.
    - i. **Bottle Change New FF55716 NOx 9.81 NO 9.9 07/29/16 1000**

- e. Substitute the labels “SO<sub>2</sub>”, “CO” for “NO, NOX” as needed in the messages.
14. Enter the new bottle concentration into the 700 calibrator if different than old bottle
- a. On the 700 calibrator, press Setup > Gas > Cyl > Port(n) where n is the appropriate port number 1-4 connected to the gas bottle
  - b. On the 700 calibrator, make sure the displayed analyte is the correct bottle. Press Edit and use the keys to enter the new concentration. The units can be changed if necessary but under normal circumstances it should stay the same.
  - c. When finished, press Enter (or Exit to cancel) and press exit enough times to return to the main screen.

### **10.6.8 Leak Check Procedures**

The purpose of this procedure is to provide guidance on determining the presence of a leak in the sample stream. The sample stream can consist of the analyzer, a water drop-out, and a sample line. This procedure also outlines how to determine if the sample manifold on a dynamic dilution calibration check system is leaking.

#### **10.6.8.1 Determination of Sample Stream Leak**

1. Disable analyzer channel on data logger (10.6.1).
2. Select Sample Pressure (Menu > Diagnostics > Pressure) and leave displayed on analyzer screen.
3. Cap the sample stream. Either:
  - a. Disconnect the sample line and cap the sample inlet on the back of the analyzer (analyzer leak check).
  - b. Cap the end of the water drop-out furthest from the analyzer (water drop-out leak check).
  - c. Cap the end of the sample line (sample stream leak check).
4. Monitor the sample pressure until a reading of less than 10” (255 mm) of mercury is reached.
  - a. If pressure is reached within 2 minutes, the leak check has passed.
  - b. If pressure is not reached within 5 minutes, leak check has failed, troubleshoot or seek assistance from site operator.
5. Uncap the sample stream by reverting steps taken in step 3.
6. Enable analyzer channel on data logger (10.6.1).
7. Leave a message for central detailing findings, including leak test conducted, passed or failed, actions taken if failed, and initials (10.6.10).

#### **10.6.8.2 Determination of Calibration Solenoid Manifold Bank Leak**

1. Using the data logger, energize the solenoid that allows gas to escape to the room (usually labeled as the dump solenoid).

- a. On an 8832, from the main screen select D>O (Display > Outputs) and scroll to the appropriate digital output. Press C for closed (O will open) – in this case the C and O refer to the circuit and C means “energize” while O means “de-energize”.
  - b. On an 8872, in the Site Node Logger Toolbox, switch to the Digital Outputs tab and click the State button in the row with the Dump Solenoid. The State button will change from OPEN to CLOSED indicating the circuit is energized.
2. On the 700, generate zero air at 2-3 Lpm while watching the pressure needle on the solenoid manifold.
    - a. Press Generate
    - b. Press the species button until “zero” appears (it may read CO/SO<sub>2</sub>/NO, etc)
    - c. Press Enter
    - d. Adjust the total flow to between 2 and 3 Lpm and press enter
  3. When the pressure needle reaches >20 (but preferably less than 30) psi, put the 700 into Standby mode.
    - a. It is normal for the pressure needle on the manifold to drop when putting the 700 into Standby. Use the post-drop number for this test.
  4. Watch the pressure needle for 2 minutes. A drop of less than 5 psi over 2 minutes indicates there is no sufficient leak.
    - a. If a drop of <5 psi occurs in 2 minutes, the leak check has passed.
    - b. If a drop of >5 psi occurs in 2 minutes, troubleshoot the manifold or the 700 (the leak could be in either in this test) or contact the site operator.
  5. Revert steps taken in step 1 to de-energize the dump solenoid.
  6. Leave a message for central detailing findings, including leak test conducted, passed or failed, actions taken if failed, and initials (10.6.10).

### 10.6.9 Time Change Procedure

The following describes the standard procedure to change the time on the Thermo CO Analyzer. First compare the Analyzer’s time with the Data logger, if it is out of the +/- 2 minute specification, then adjust the Analyzer’s time. Check the Data logger’s time with cell phone time, if it is significantly off, contact the Data Manager.

**Important Note!** – All times on data loggers and analyzers are to be set to Mountain Standard Time and do not adjust for daylight savings. Data logger and analyzers clocks should appear to be running 1 hour late from March to November (daylight savings time period, clocks move one hour forward). Reference a calendar or other source to determine the exact and end dates of daylight savings.

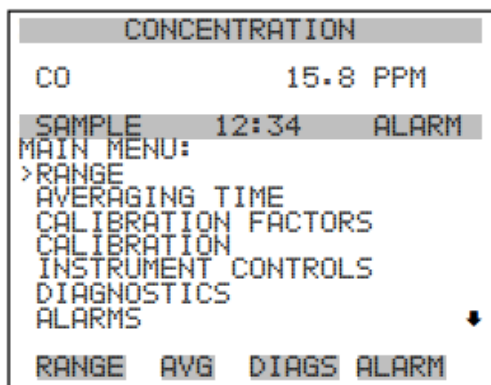
#### Analyzer

This procedure was taken from the Thermo CO analyzer manual. For any time changes done to the analyzer make a note on the analyzer log sheet.

*Thermo 48i:*

1. Press the Main Menu  button

2. In the Main Menu:

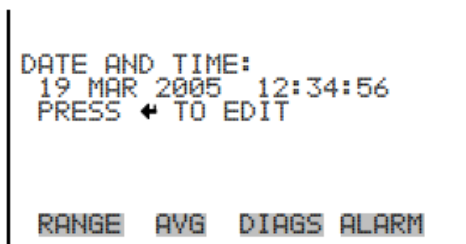


Use the arrow keys to choose **INSTRUMENT CONTROLS** and press

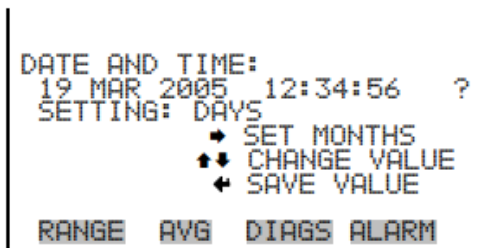
**ENTER**




3. Navigate to the **Date/Time** and press **ENTER**



4. Press **ENTER** to edit



5. Use the right arrow pushbutton until “**SETTING:**” displays the unit of time desired for changing.
6. Set the correct time using the up or down arrow pushbuttons
7. Press **ENTER** to save the new time

8. Press **RUN**  to exit and return to the run screen

#### Data logger

If the clock on a data logger is incorrect, there may be more serious issues to consider including data validity and proper operation of the data logger. Contact the Data Manager.

#### **10.6.10 Message to Central Procedure**

##### ESC 8816 or 8832

1. Log in to the data logger.
2. From the top level menu Type **SMC (S Status Menu > M Message Menu > C Leave a Message for Central)** followed by hitting the **Enter** or **Return** key.
3. When the text entry display appears, type in up to 80 characters of text explaining the site visit, followed by your initials, example, “Weekly completed. No problems noted. – JJ” then hit the **Enter** or **Return** key on the keyboard to accept the log entry.

##### Agilaire 8872

1. Log in to the data logger using the AirVision™ application.
2. Select the **Home** tab > then **Data Editors** drop down menu.
3. From the drop-down menu select, **LogBook Entry Editor**, and click the round green icon with white “plus” symbol, entitled, **New Log Entry**.
4. Next, click on the **Category:** drop-drop down menu and choose **Logger Message**.
5. Select the drop-down menu item, **Site** and choose the appropriate site, for example, **Welby**.
6. Enter text explaining the purpose of the site visit, followed by your initials. Example, “Weekly completed. No problems noted. – JJ” hit the **Save** button at the top left to save your comments. The application will allow more characters than 80, but they are truncated for the Central computer.

#### **10.6.11 Line change Procedure**

1. All sample lines are to be changed annually or as needed if defects are suspected. Through the probe calibration lines are to be changed once every three years or when defects or degradation are suspected. Sample lines should be trimmed by approximately 1’ six months after installation and replaced annually.
2. Disable analyzer channel on data logger (10.6.1).
3. Perform a leak check on the existing sample line to confirm data validity prior to changing the line (10.6.8).
4. Remove the existing line and measure out and cut a length of new sample line of approximately the same length as the old line. Use a designated tubing cutter to cut the Teflon tubing to ensure the cut is straight, at a 90 degree angle to the tubing’s outer wall, and not beveled.

5. Cover or cap the end of the new line prior to installation. This ensures dirt does not enter the line during the installation process. Remove the line cover or cap once the line is installed.
6. Note the final length of sample line.
7. Ensure fitting used in the sample train are made of Teflon. Borosilicate glass and stainless steel fitting can be used, however, their usage is less desirable and Teflon fittings should be used if available. The usage of dissimilar fitting materials is discouraged because of the potential for thread damage and improper sealing.
8. Clean water dropout manifold (if equipped).
9. Perform a leak check on the new sample line (10.6.8).
10. If the line replaced is a sample line, note sample line length and determine residence time. All residence times must be < 20 sec, except for CO where the residence time should be < 20 sec. CO is a non-reactive gas and does not require strict adherence to the < 20 sec criteria, except at an NCore site. The calculation of residence time requires knowledge of the sample flow rate, length of sample line, additional static volumes such as water dropouts, and the internal cross-sectional area of the tubing. When determining additional a static volume, such as a water dropout, use only the volume that sees active gas flow. For example, the water catch flask on the bottom of the water dropout should not be included in volume calculations, only the upper portion of the manifold. Sample flow rate can be attained from the analyzers front panel, however, if the analyzer flow sensor has not been verified by a certified flow transfer standard within the past 6 months, then a certified flow transfer must be use to determine flow rate. This can be accomplished by attaching a certified flow transfer standard to the sample line inlet. All flows are to measured at standard temperature and pressure (25 °C and 1 atm).

Below is a table of internal cross-sectional areas for common types 1/4 Teflon tubes that can be use in residence time calculations.

**Table 4. Internal Cross-Sectional Area for Teflon Tubing**

Tubing Diameter	ID	OD	ID Area
Thin Wall (3/16 x 1/4)	4.8 mm	6.35 mm	18.10 mm <sup>2</sup>
Medium Wall (5/32 x 1/4)	4.0 mm	6.35 mm	12.57 mm <sup>2</sup>
Thick Wall (1/8 x 1/4)	3.2 mm	6.35 mm	8.04 mm <sup>2</sup>

(Note\* 1 cm<sup>3</sup> = 1 ml)

**Equation 7. Residence Time**

$$\text{Residence Time (sec)} = \left( \frac{\left( \left( \frac{\text{ID area of tube (mm}^2\text{)} \times \text{Tube Length (in)} \times 2.54 \left( \frac{\text{cm}}{\text{in}} \right)}{100 \left( \frac{\text{mm}^2}{\text{cm}^2} \right)} \right) + \text{Static Vol. (cm}^3\text{)} \right)}{\text{Sample Flow} \left( \frac{\text{cm}^3}{\text{min}} \right)} \right) \times 60 \left( \frac{\text{sec}}{\text{min}} \right)$$

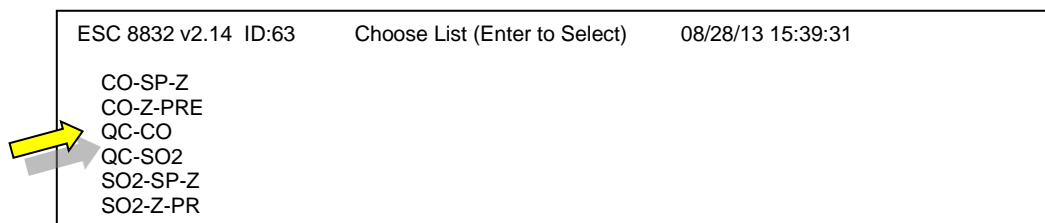
11. Enable analyzer channel on data logger (10.6.1).
12. Note line change activities on log sheet.

13. Enter message to central, including the new residence times (10.6.10).

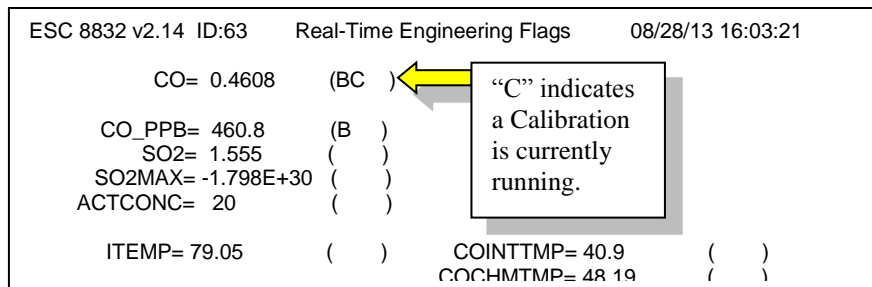
### 10.6.12 Perform Manual Precisions

#### ESC 8816 or 8832

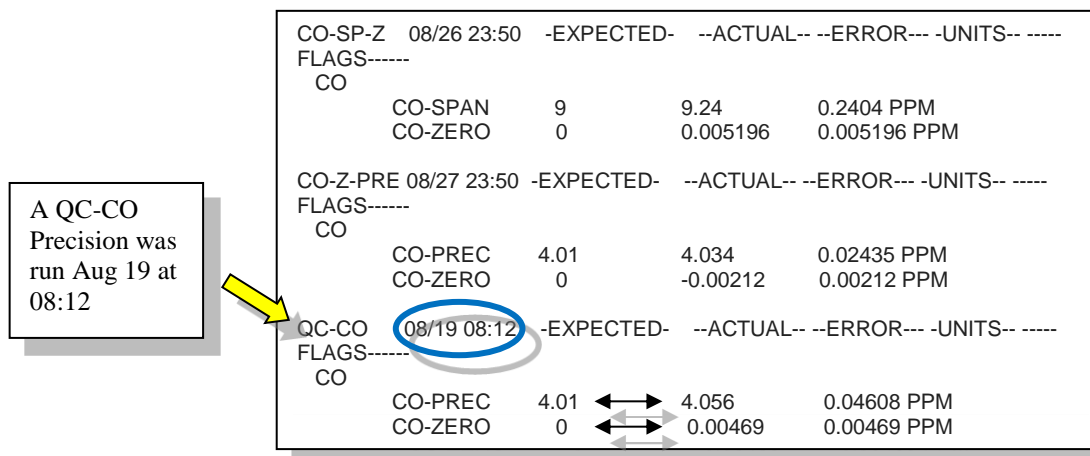
1. Login to the data logger.
2. From the top level menu type **CCS** (**C Configuration Menu** > **C Configure Calibrations** > **S Start a Calibration Program**.)
3. A list of calibration options appears (see below) To run a Quality Control CO Precision select, **QC-CO** by scrolling down to that option and hitting the **Enter** or **Return** key.



4. Hit the Esc (escape) key twice to get back to the top level menu, then type, DF to verify the Precision Calibration was initiated. You should see the letter, “C” next to the CO reading indicating it is in the calibration mode, as shown. It will run for about 10 minutes. After a Manual Precision has run to completion, the new precision value will appear in the RL list.



5. Hit the **Esc** key twice to get to the top level menu then type **RL** to view, shown below.
6. Continue to step 8 in the [Agilaire 8872](#) section



### Agilaire 8872

1. Login to the 8872 data logger.
2. From the **Home** tab select **Utilities > Site Node Logger Toolbox**.
3. When the **Site Node Logger Toolbox** tab appears, select the **Calibration** tab. Once the Sequence Name page appears, select the proper calibration sequence that you wish to run. Each precision choice will have “pre” in the Sequence Name. For example, to run an ozone Precision, at the right side of the window click on **Start** in the “O3-Z-Pre” row. For CO and O3 it will take approximately 25 minutes to get the results back. For SO2 and NO2 it can take an hour or longer.
4. Once the Precision has completed, on the **Home** tab click on **Reports**. From the drop-down menu, select **Calibration Results**.
5. When the “Report Criteria” window appears, notice the “Parameter Selection” section. On the keyboard, hold the **Ctrl** button down and click on each parameter for which you wish to see calibration results. Example, click on **ACTCONC**, **CO**, **NO**, **NO2**, **NOX**, and **O3CAL**, and **SO2** (or a subset of these depending on the site and available equipment.)
6. Now look at the “Date Range” section of the window. Modify the “Start Date” and time and “End Date” and time to coincide with the Precisions that you just ran.
7. Finally in the “Calibrations Results” section click on **Generate Report** to see the Precision results, presented in a report format.
  - a. The “Value” column will show the average value collected by the analyzer. The “Expected Value” column contains the value that should have been generated by the calibration equipment. With O3, the O3 Cal “Expected Value” column shows the value the O3 calibration equipment was attempting to generate and the “Value” column shows what it actually did generate. With NO2, the ACTCONC section “Expected Value” column shows the value the NO2 calibration equipment was attempting to generate and the “Value” column shows what it actually did generate.
8. Enter the results into the ZSPTracking database within 48 hours of completion.
  - a. Open the database and click on Enter Manual
  - b. In the new form, select your site from the Site Name drop list
  - c. Select the appropriate criteria pollutant from the pollutant drop list. Note that the first pollutant is automatically selected.
  - d. Click Get
  - e. Verify the fields against the “Calibrations Results” report. If correct, click Capture Data. If not, contact the data manager.

### **10.7 Calibration Standards**

Refer to the Standards Verification/Calibration SOP in the CDPHE/APCD/TSP QAPP for more detailed information on standards and traceability of gas standards.

## **11 HANDLING AND PRESERVATION**

Atmospheric carbon monoxide concentrations are monitored continuously; no discrete samples are collected, handled, or preserved. Therefore a section for sample handling and preservation in this SOP is not required.

## **12 SAMPLE PRESERVATION AND ANALYSIS**

Carbon monoxide samples receive no special preparation prior to analysis. Therefore a section for sample preservation and analysis in this SOP is not required.

## **13 TROUBLESHOOTING**

### **13.1 Environmental Factors**

Environmental conditions can play a role in the operational characteristics of analyzers. Some external factors may be constant while others are sporadic in nature. External factors to check include:

1. Is the shelter temperature stable throughout the day?
2. Is vibration from other equipment causing an effect?
3. Is the air conditioner or heater blowing directly on the instrument?

### **13.2 General Factors**

Other factors linked to the shelter and manifold design can contribute to data loss. The sample probe, water dropouts and sample lines should be checked on a regular basis to ensure integrity. Dirty sample lines can artificially suppress readings of reactive analytes. The sample probe weather cap inlet should be cleaned every six months and the sample lines replaced every year. Ozone sample lines are to be trimmed mid-year, where 2 feet of sample line is trimmed from the end of the inlet of the sample line to remove dirt that normally collects along the inside of the sample line near the inlet. Through-the-probe (TTP) calibration lines are to be replaced once every three years and 6" trims of the inlet side of the calibration line are to be performed in the other years. The particulate filters used to protect the analyzers should be changed on a regular basis, as outlined in the specific instrument manuals and SOPs. Filters 48i-TLE should be changed during the monthly site visit at a minimum.

Power to the site is another factor that can contribute to data loss. Incoming power needs to be stable and have a good waveform.

### **13.3 Instrument Troubleshooting**

Troubleshooting of problems with analyzers is specific to each analyzer and its design. Common problems with instruments include:

1. Low or erratic flow
2. Erratic or noisy readings
3. No readings or off-scale readings
4. No display
5. No output
6. Analyzer completely inoperative

Troubleshooting sections in specific analyzer operation and service manuals, located at each site or in the APCD office, should be consulted to assist in resolving instrument problems. Equipment used in troubleshooting includes digital voltmeters.

Chapter 6 outlines troubleshooting techniques in the 48i-TLE manual. Troubleshooting techniques for the data logger and remaining sample system, including any external solenoid manifolds and calibration systems, are the purview of their respective manuals and the experience of qualified operators.

## **14 DATA ACQUISITION, CALCULATIONS, AND DATA REDUCTION**

Originally, ink-pen strip chart recorders were used by the APCD as a primary record of data from air monitoring instruments. Hourly averages were then hand-interpreted from these charts. Today, due to advances in data storage and retrieval systems, these ink-pen strip chart recorders are no longer in use. Instead, all data are now collected, stored, and retrieved digitally from data loggers. The terms data logger and onsite data acquisition system are used interchangeably throughout this SOP.

### **14.1 Data Acquisition**

The APCD/TSP data acquisition system (DAS) is comprised of three components: an onsite primary data acquisition system that collects data from all continuous monitoring equipment, an onsite secondary data acquisition system, or back-up system that collects data from the continuous monitoring equipment, and a centralized central polling system that routinely collects data from the primary data acquisition system and stores it in a SQL database for processing and validation.

#### **14.1.1 Primary Onsite Data Acquisition Systems**

The APCD employs three different models of onsite DAS in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, and the Agilaire 8872 data logger. The 8816 data logger is the oldest type of data logger in the network and is a predecessor to the 8832 and 8872 data loggers. See Section 8.1.4 for a more detailed description of these data loggers.

#### **14.1.2 Secondary Onsite Data Acquisition Systems**

The APCD uses two different data acquisition systems to provide backup data in case of failure of the primary systems. The backup data acquisitions systems are the analyzer based on-board data acquisition systems that are unique to each manufacturer. Internal data logging is available on the newer Thermo and Teledyne Air Pollution Instrumentation (TAPI) analyzers. A description of these secondary data acquisition systems are as follows.

##### Teledyne iDAS System

The TAPI internal data acquisition system (iDAS) is available on all analyzers. The non-volatile memory retains the data even when the instrument is powered off or the firmware is updated (back up before update advised). Access to the iDAS is available either through the front panel or the APICOM remote interface. The remote interface allows for data to be automatically downloaded to a remote PC. The iDAS is flexible in the parameters stored and triggering events to initiate data storage. The maximum iDAS data storage is limited to the analyzers available memory and the number of data parameters and channels.

##### Thermo Internal Data Logging System

The Thermo internal data logging is available in the 48i-TLE CO analyzer. The data is stored in memory on the C-Link Board, which is powered by a +5 volt battery when the instrument power is off. The internal data logging settings and data are accessible through the remote interface iPort software. The 48i-TLE also allows for front panel access to the internal data logging menu. The 48i-TLE has a significant amount of memory. Allocating 70% of the

available memory will allow for 168 days worth of long records, using a 1 minute averaging period for concentrations.

### **14.1.3 Central Polling System**

The APCD uses the AirVision software package for its central data management system. “AirVision is a centralized data management and polling software system that is used to acquire, edit, validate, analyze, and report air quality data. AirVision supports open data acquisition and data imports thru modular drivers that can be added to provide connectivity to a data source. The system has combined data editing and quality control tools that can be utilized in evaluating and validating data in the post-processing environment. The post-processing environment allows user control of the data from the management of raw data within the server environment through the exporting of validated data through built in reports or for external statistical evaluations and reporting. A more detailed description of this application can be found in APCD’s Data Logger and Central Polling Standard Operating Procedure.” (Agilaire, 2009)

#### **Central Polling Daily Tasks**

1. Task managers within Air Vision polls data from remote air quality monitoring sites at the top of each hour, at a minimum. Some sites may be polled at a greater frequency depending upon data needs. Data from each site is stored in a SQL database and made available for review and analysis after polling has been completed.
2. Ambient data on the AirVision Central polling computer is reviewed every business day in the morning, the previous 24 hours (or 3 days on Mondays) worth of data is reviewed for completeness and accuracy. This data review is used to determine if a physical site visit is required.
3. Low level (precision) and high level (span) test gas sequences are run on alternate days. The precision and span level tests are followed by a zero test and a two-minute recovery period. The results are reviewed each morning and plotted on control charts. It is the responsibility of one individual within TSP to review the daily Zero/Span results, plot them on the control charts, and notify the technician responsible of any out of control condition. "Out of control" is defined as:
  - a. trending toward warning limit as defined on the control chart
  - b. points plotted exceeding the warning limit
  - c. points plotted exceeding the action limit as defined on the control chart

### **14.2 Calculations and Data Reduction**

As mentioned above, data collected on a DAS are available as soon as the averaging period is complete. Data are polled automatically via modems (analog phone, wireless cellular, or DSL) by the Central polling computer hourly. If needed, sub-hourly polls or remote checks can also be performed.

Data from the continuous air monitoring equipment are generally stored at hourly and minute resolution averages. The software on the Central polling computer stores the downloaded minute and hourly averages and is capable of aggregating these averaging intervals into larger averaging intervals such as 8-hour or 24-hour averages.

A more detailed description of the DAS is given in the CDPHE/APCD/TSP QAPP and in the manufacturers’ manual.

#### **14.2.1 Zero Adjustment Methods**

CO analyzers are unique in that the baseline drift of signal upwards is expected due to the dirtying of the analyzer's analytical systems. Typically, the dirtier the sample matrix the more rapid the baseline drift. Because this drift is so predictable, the APCD feels that compensations for this drift, whether by the analyzer or by post-processing, is appropriate and acceptable.

#### Thermo 48i – TLE

The Thermo i-series instruments, used by the APCD, are equipped with an auto-zero function that allows the instrument to automatically check and adjust the zero background on a periodic basis. While the gas-filter correlation IR measurement method used by this analyzer can provide highly specific, accurate and precise data, the ability to make continuous measurements at low ppm concentrations may be limited by gradual changes in electronic baseline, or zero background. This drift occurs primarily due to slight changes in environmental parameters, such as temperature or correlation wheels collecting dust. The enhanced trace level version of the 48i CO analyzer uses both hardware and software compensation to limit the impact of changes in the instrument's environment. While the auto-zero function greatly improves instrument stability, it is not intended to replace the routine calibration procedure. Thermo Fischer Scientific suggests the analyzer be programmed to make actual adjustments every two hours, however the APCD has found that adjustments made every six hours (03:00, 09:00, 15:00, 21:00hrs) to be sufficient. Post processing of this data and Quality Control data by APCD for additional zero adjustments are not made.

### **15 COMPUTER HARDWARE AND SOFTWARE**

The data acquisition system (DAS) used by the APCD/TSP for collecting data from continuous air monitors is generally described in Section 14 and in the CDPHE/APCD/TSP QAPP.

The primary DAS Central polling computer is a Windows based server. The Airvision data system on this server provides for polling the sites using dial-up modems and broadband access for data. A printer is attached to the system for printing out reports. The primary repository for data, and the engine for information assembly, is the Microsoft SQL Server operated and maintained by the Governor's Office of Information Technology. The CDPHE/APCD/TSP maintains a database owner position responsible for logical maintenance of the data system.

The 8872 is a Windows based PC with attached monitor, keyboard, and mouse. The 8832 and 8816 are proprietary hard-circuit systems that may or may not have attached screens and keyboards. Sites usually include other computer hardware and software such as switches, RS232 cables, Ethernet cables, and analog cables.

### **16 DATA MANAGEMENT AND RECORDS MANAGEMENT**

#### **16.1 Data Management**

Data are generated from the analyzer at intervals internally set, ranging from an averaging time of 20 seconds to 5 minutes. The data is collected by the on-site data logger as near-real-time data (often every 3 to 10 seconds) and is aggregated into 1-minute averages, which are in turn aggregated into 1-hour averages. Some data streams may be stored at a third averaging interval, meteorological data can be stored as a 15-minute average and SO<sub>2</sub> data can be stored in a 5-minute average. Note the capacity of the on-site data logger is limited to three time-base averaging intervals and that the 5-minute SO<sub>2</sub> average supersedes the 15-minute meteorological average. The Central polling computer collects these averages routinely.

For reporting purposes, other averaging intervals are derived, such as an 8-hour moving average for ozone. In these cases, the data is aggregated by the Central polling computer for the purpose of the report and are often not stored independently. The Central polling computer connects to a SQL server, which is maintained, and backed up, by the Office of Information Technology.

Data are sent to the EPA centralized Air Quality System (AQS) database for long-term storage. Additionally, the data are stored and archived by the APCD/TSP in both electronic and hard copy formats. Monthly electronic data files and related printed material packets (maintenance forms, etc.) are produced.

A more detailed description of the data management is given in the Data Processing Central SOP in the CDPHE/APCD/TSP QAPP.

## 16.2 Records Management

Continuous ambient air monitoring data are archived both in electronic and hard-copy formats. Electronic data and calibration files from the primary DAS are archived. Data from the backup electronic strip chart recorders, where used, are downloaded annually and archived on a computer hard drive. Hard copy printouts of the data are kept at the APCD office for a minimum of three calendar years before being sent to an off-site archive/storage facility.

## 17 QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control are two terms commonly discussed, but often confused. Quality assurance refers to the overall process of ensuring that the data collected meet previously stated Data Quality Indicators (DQI) and associated measurement quality objectives (MQOs). The principal DQIs are precision, bias, representativeness, completeness, comparability, and sensitivity. The principal MQO's are parameter specific and are listed in CDPHE's QAPP. Guidance for developing DQI's and MQO's is given in EPA's Quality Assurance Handbook (US EPA, 2013). Quality control covers specific procedures established for obtaining and maintaining data collection within those limits.

### 17.1 Quality Assurance

The goal of the quality assurance program is to control measurement uncertainty to an acceptable level through the use of various quality control and evaluation techniques. The entire Quality Assurance effort put forward by the APCD is too large to include here. The scope of this SOP will describe efforts taken by site operators and data validation personnel to ensure the quality of the data collected meets standards set forth in various sections of the *Code of Federal Regulations*. For a complete description of the Quality Assurance and Quality Control process undertaken by the APCD, see the appropriate quality assurance appendices in the QAPP. Two of the most significant Quality Assurance procedures are described below.

#### 17.1.1 Audits

Audits are evaluation processes used to measure the performance or effectiveness of a system and its elements. APCD quality assurance staff performs two types of audits. These audits are performed at a frequency as described in APCD QAPP.

**Systems Audits** - A systems audit is an on-site review and inspection of an ambient air monitoring program or air monitoring site to assess its compliance with established regulations governing the collection, analysis, validation, and reporting of ambient air quality data.

**Performance Audits** - A performance audit is a type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst, laboratory, or measurement system. Two types of performance audits discussed below.

- Monitoring Organization Performance Audits - These performance audits are used to provide an independent assessment of the measurement operations of each instrument being audited. This is accomplished by comparing performance samples or devices of "known" concentrations or values to the values measured by the instruments being audited. Detailed information about how specific audits are performed can be found in the Quality Assurance SOPs section.
- National Performance Evaluation Program (NPEP) - These performance audits are implemented at the federal level although some programs may be implemented by the monitoring organizations if certain requirements are met.

### 17.1.2 Data Quality Assessment

Data Quality Assessment is used to assess the type, quantity, and quality of data in order to verify that the planning objectives, Quality Assurance Project Plan components, and sample collection procedures were satisfied and that the data are suitable for its intended purpose. Data Quality Assessment is a five-step procedure for determining statistically whether or not a data set is suitable for its intended purpose. This assessment is a scientific and statistical evaluation of data to determine if it is of the type, quantity, and quality needed and is performed annually by quality assurance staff to check if objectives were met.

## 17.2 Quality Control

Quality Control is the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the EPA. Quality control includes establishing specifications or acceptance criteria for each quality characteristic of the monitoring/analytical process, assessing procedures used in the monitoring/analytical process to determine conformance to these specifications, and taking any necessary corrective actions to bring them into conformance.

Quality control refers to procedures established for collecting data within pre-specified tolerance limits. These pre-specified tolerances are defined in the Measurement Quality Objectives as defined in APCD's QAPP. While all Quality Control procedures are important, the most significant procedure employed by the APCD is the routine measurement of a known test gas by gaseous analyzers. All procedure documented in this SOP are Quality Control procedures because they allow the analytical systems to continue running in exceptional condition and serves to minimize out-of-control conditions as defined by APCD MQO's. By definition, the creation and use of this SOP is a Quality Control function. All Quality Control procedures are described in Sections **Error! Reference source not found.** and 0 of this SOP. Three of the most significant Quality Control procedures are described below.

### 17.2.1 Performance and Precision Tests

A primary quality assurance task carried out by site operators is the performance of routine QC checks. The APCD performs two types of QC checks at the above mentioned precision level test gas concentrations. These two tests are called Performance checks and QC Precision checks. The former is an automated performance test that is performed nightly and is used to evaluate the health of the sample system. The latter is a manual evaluation performed by qualified personnel who can attest to their validity and are reported to the EPA. The former are not reported to the EPA to prevent an artificial bias introduced by the large sample pool. Sites operated by subcontractors are not required to manually perform QC Precision checks. Instead, one performance check is selected at random from each two-week period to satisfy the QC Precision check requirement. The performance check is selected by APCD personnel and is included with the APCD-operated QC Precision check submission to the EPA's AQS.

For instructions on performing a manual precision Quality Control check, see Section 10.6.12.

### 17.2.2 Calibrations

Calibration of an analyzer or instrument establishes the quantitative relationship between the actual value of a standard, be it a pollutant concentration, a temperature, or a mass value, and the analyzer's response (chart recorder reading, output volts, digital output, etc.). This relationship is used to convert subsequent analyzer response values to corresponding concentrations. Once an instrument's calibration relationship is established, it is checked at reasonable frequencies to verify that it remains in calibration. It is the goal of APCD to perform calibrations on all analyzers quarterly, however, circumstances may require calibrations be performed at the longer frequency of every 6-months. A 6-month calibration frequency still meets EPA recommended calibration frequency criteria.

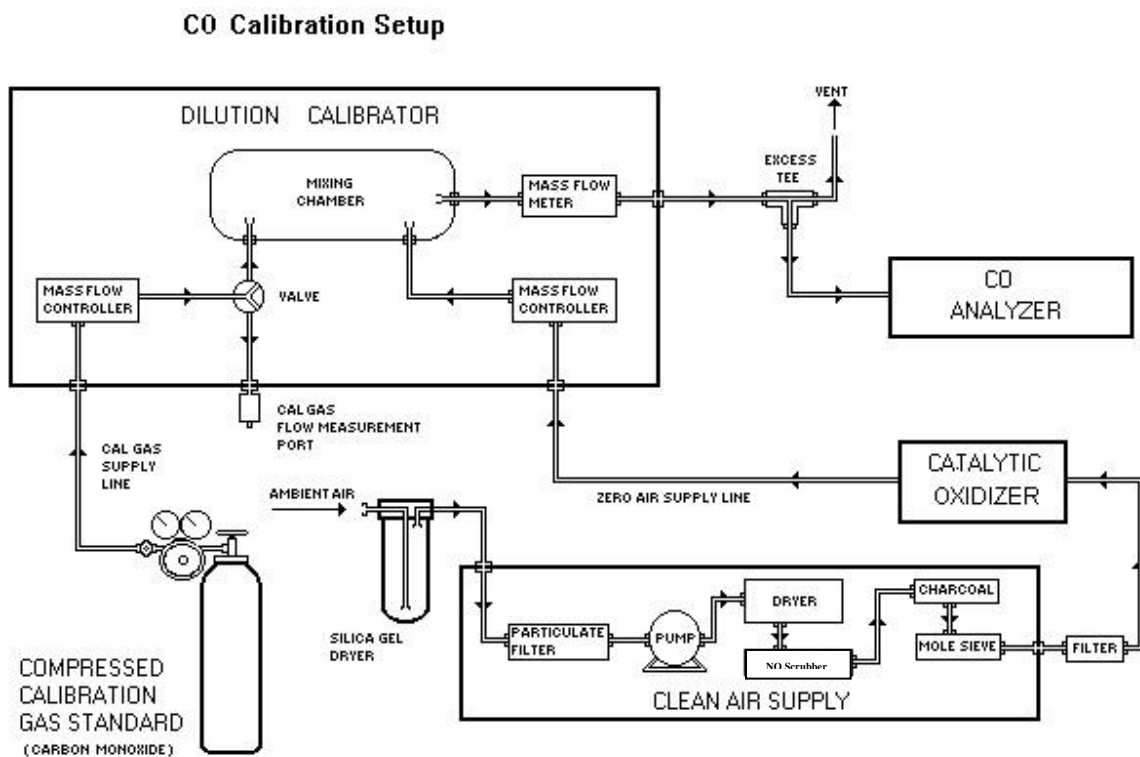
For instructions on performing a calibration, see Section **Error! Reference source not found.**

### 17.2.3 Documentation

Documentation is an important component of the quality control system. Extensive certification paperwork and log sheet must be rigorously maintained for procedures, standards and analyzers. APCD takes special care to prepare and preserve backup copies of all data, especially calibration data. All data and supporting documentation should be held on-site for a minimum of three calendar years then sent for offsite archive. See Section 16 for additional information.

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**Figure 1. CO Calibration Setup**

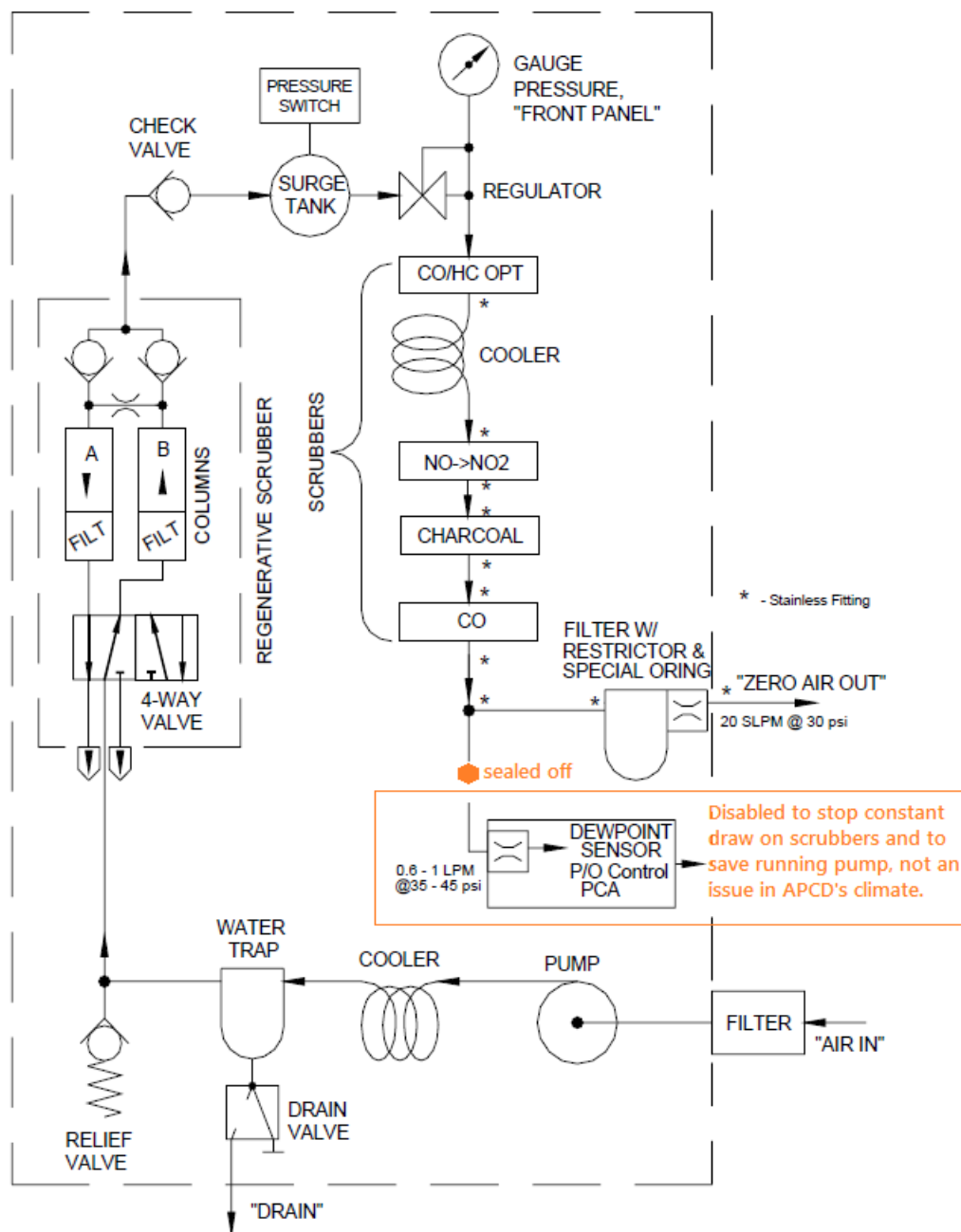


Figure 2. Typical zero-air supply system - TAP 701H

Calibration \ Audit: AA ET SC

[illegible]

COMMENTS _____	50.0 _____	_____
_____	35.0 _____	_____
_____	25.0 _____	_____
_____	15.0 _____	_____
_____	9.0 _____	_____

**Figure 3. Calibration/Audit Worksheet**

FLOW MEASUREMENT

STATION \_\_\_\_\_ DATE \_\_\_\_\_

CALIBRATOR \_\_\_\_\_ ZERO AIR \_\_\_\_\_ VAC = \_\_\_\_\_ " PSI = \_\_\_\_\_ "

CATALYTIC OXIDIZER at \_\_\_\_\_ mv/ \_\_\_\_\_ F/C

GAS REGULATOR \_\_\_\_\_

STANDARD CYL # \_\_\_\_\_ PRESS = \_\_\_\_\_ / \_\_\_\_\_ CONC = \_\_\_\_\_

CAL SETTING	RAW FLOW MEASURED	AVG FLOW	TEMP °C	(BP-Pv) * 298.2 29.92 * (273.1 T)	FLOW CONC * Fg PPM @STP (Fd + Fg) OUT
		$\bar{X} =$	$\bar{X} =$	$(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \frac{\quad}{\quad})}$ CF =	
		$\bar{X} =$	$\bar{X} =$	$(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \frac{\quad}{\quad})}$ CF =	
		$\bar{X} =$	$\bar{X} =$	$(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \frac{\quad}{\quad})}$ CF =	
		$\bar{X} =$	$\bar{X} =$	$(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \frac{\quad}{\quad})}$ CF =	
		$\bar{X} =$	$\bar{X} =$	$(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \frac{\quad}{\quad})}$ CF =	
		$\bar{X} =$	$\bar{X} =$	$(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \frac{\quad}{\quad})}$ CF =	
		$\bar{X} =$	$\bar{X} =$	$(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \frac{\quad}{\quad})}$ CF =	

CALIBRATOR FLOW \_\_\_\_\_ Total \_\_\_\_\_ Excess \_\_\_\_\_ FLOW STANDARD = Make and SN # \_\_\_\_\_  
 Rotometer \_\_\_\_\_ mb or HBM - 1 # \_\_\_\_\_

BP = Barometric Pressure "Hg  
 STP = 25° C & 29.92 "Hg  
 Fd = Flow rate of dilution air  
 Fg = Flow rate of gas standard

Pv = Vapor  
 T = Temperature  
 CF = Correction Factor (dimensionless) to  
 compensate flow for temp/barometric pressure

COMMENTS

Figure 3 (continued)



**COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT**

Air Pollution Control Division - Technical Services Program  
Ozone, Carbon Monoxide, Sulfur Dioxide Calibration Form



<b>Site Name:</b> _____													
<b>Site Info.</b>				<b>Date Time</b>				<b>Calibration Equipment Info</b>					
AQS ID: _____				Date (mm/dd/yy): _____				Calibrator Type: _____					
Parameter: _____				Time (hh:mm): _____				Calibrator SN: _____					
Analyzer Type: _____				Prev Cal. Date (mm/dd/yy): _____				Calibrator Cert Date: _____					
Analyzer SN: _____				Calibrator's Initials: _____				Cert. Slope (m): 1.00000					
<b>Site Precision Source Info.</b>								Cert. Intercept (b): 0.00000					
Source Type: _____								<b>Calibration Gas Info.</b>					
Source SN: _____								Bottle SN: _____					
Conc.: _____								Conc.: _____					
Exp. Date: _____								Exp. Date: _____					
<b>Pre-Calibration System ZSP Evaluation</b>						<b>Post-Calibration System ZSP Evaluation</b>							
Pre-Calibration Analyzer Slope: _____						Post-Calibration Analyzer Slope: _____							
Pre-Calibration Analyzer Intercept: _____						Post-Calibration Analyzer Intercept: _____							
Set Point	Source Conc.	Display Conc.	DAS Conc.	Display % Diff	DAS % Diff	Set Point	Source Conc.	Display Conc.	DAS Conc.	Display % Diff	DAS % Diff		
Zero						Zero							
Span						Span							
Precision						Precision							
<b>Pre-Calibration Points</b>						<b>Post-Calibration Points</b>							
Set Point	Conc. Out Conc.	DAS Conc.	Conc. Adj Conc.	DAS % Diff	Best Fit DAS Conc.	Best Fit (% RE)	Set Point	Conc. Out Conc.	DAS Conc.	Conc. Adj Conc.	DAS % Diff	Best Fit DAS Conc.	Best Fit (% RE)
Zero							Zero						
Level 1							Level 1						
Level 2							Level 2						
Level 3							Level 3						
Level 4							Level 4						
Level 5							Level 5						
Level 6							Level 6						
Level 7							Level 7						
<b>Pre - Regression Results</b>						<b>Post - Regression Results</b>							
Slope: _____						Slope: _____							
Intercept: _____						Intercept: _____							
R2: _____						R2: _____							
<b>Comments:</b>													

**Figure 4. Calibration Report**

### Figure 5. Station and Met Log

<b>CO Thermo 48</b>		sn: _____ / _____		STATION: _____			
		1: C I	2: C I			/	
Monthly Station						Month	Year
Activities Log	Date						
Slope (COEF)	0.5 - 2.0						
Intercept (BKG)	<10						
Bias Voltage	C: -105 - -115 I: -130 - -100						
Internal Temp	C: 8 - 47 I: 15 - 45						
Bench Temp	C: 40 - 52 I: 35 - 55						
Sample Pressure	250 - 1000						
Sample Flow	C: 0.35 - 2.5 I: 0.35 - 1.5						
S/R Ratio	C: 1.14 - 1.18 I: 1.00 - 1.18						
AGC Intensity	150k - 300k						
Motor Speed	100						
Clock	+/- 2 min						
Dessicant	Changed?						
Filter	Changed?						
Leak Check	<250 S Press						
Operator							
OAS (Monthly), >30 Days Initials							
Day	Time	Action				Initials	Date Online

Figure 6. CO Log

**MAINTENANCE REPORT**

DATE \_\_\_\_\_  
STATION \_\_\_\_\_  
ASSIGNED TO \_\_\_\_\_  
ORIGINATED BY \_\_\_\_\_  
ANALYZER or EQUIPMENT \_\_\_\_\_ S/N \_\_\_\_\_

**MALFUNCTION DESCRIPTION OR COMPLAINT**


**ACTION TAKEN**


**DATA TO BE DELETED (IF ANY)**  
**ENTER EXACT DATES AND DATA HOURS**


COMPLETED BY \_\_\_\_\_  
COMPLETION DATE \_\_\_\_\_

Figure 7. Maintenance Report Form

### Providing CO free air for use in ambient air analyzers

Carbon monoxide analyzers used by the APCD require a source of CO free air to periodically check baseline response. This is usually performed by a scrubber of catalytic material commonly known as Hopcalite or Carulite which is a built in feature of analyzers and zero air sources operated by the APCD. Both of these catalysts are oxidative catalysts in the Hopcalite-family of catalysts, which are brown/black in color whose primary constituents are manganese dioxide (MnO<sub>2</sub>) and copper oxide (CuO). Carbon monoxide in the presence of oxygen will react on the surface of select metal oxide catalysts to oxidize carbon monoxide to carbon dioxide.



In comparison with other transition metal compounds, manganese oxides are more effective for the low temperature oxidation of CO. The combination of MnO<sub>x</sub> with other metal oxides (CuO), in select conditions, exhibit significantly higher catalytic activity for the conversion of CO to CO<sub>2</sub> when compared to MnO<sub>x</sub> oxides alone. Additionally, the manganese oxide derived substrates are friendlier towards the environment when compared to other metal oxide catalysts.

The effectiveness of the Hopcalite/Carulite scrubber installed on each CO analyzer is measured at the time of calibration and during audits. Since a zero standard does not exist that meets the analyzers lower limit of detection, a round robin approach between the site analyzer, the calibration zero air supply, and the auditor zero air supply is used. These systems are operated and maintained by independent people and provides for an evaluation of the zero air supply systems that can effectively identify when a system begins to operate outside acceptable levels.

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Ardita Mele, Ilo Mele and Altin Mele

Department of Chemistry, Faculty of Natural Sciences, University of Tirana, Albania

American Journal of Applied Sciences 9 (2): 265-270, 2012

ISSN 1546-9239

##### Catalytic Oxidation of Carbon Monoxide over Transition Metal Oxides

Sebastien Royer and Daniel Duprez

Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim

ChemCatChem, 3 (1): 24 - 65, 2011

DOI: 10.1002/cctc.201000378

**Figure 8. Hopcalite/Carulite Scrubber**